With the Author's Compts

House-Drainage, Sewerage and Sewage Disposal in Relation to Health

LOUIS C. PARKES, M.D., D.P.H.

LONDON
H. K. LEWIS 136 GOWER STREET, W.C.

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BY

LOUIS C. PARKES, M.D., D.P.H.

CONSULTING SANITARY ADVISER TO H.M. OFFICE OF WORKS, AND TO THE RECEIVER FOR THE METROPOLITAN POLICE DISTRICT; CIVILIAN SANITARY MEMBER OF THE ADVISORY BOARD FOR ARMY MEDICAL SERVICES (WAR OFFICE); MEDICAL OFFICER OF HEALTH OF THE METROPOLITAN BOROUGH OF CHELSEA; EXAMINER IN HYGIENE FOR THE UNIVERSITY OF LONDON; FELLOW OF THE ROYAL SANITARY INSTITUTE AND MEMBER OF COUNCIL

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H. K. LEWIS, 136 GOWER STREET, W.C.

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PREFACE

These lectures were delivered at the University of London in February 1909, under the Trust created by the Will of the late Sir Edwin Chadwick, K.C.B., in 1895, and in accordance with a scheme approved by the Senate of the University. The official title of the course of lectures is "The Medical Aspects of Recent Advances in Hygiene as connected with Sewering."

L. C. P.

61, Cadogan Square, S.W.
March 1909.

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INTRODUCTORY

THE LIFE OF SIR EDWIN CHADWICK, K.C.B.

A few words, as Introduction, on the life and career of Sir Edwin Chadwick, whose name is associated with this course of lectures, will not be out of place.

Chadwick was born near Manchester in 1800. After leaving school, he studied law, and was called to the bar in 1830. At an early period of his life he commenced to devote his attention to questions of social, sanitary, and political science, and contributed magazine articles on "Life Assurance" (1828), "Preventive Police," and "Public Charities in France" (1829). In 1832 he was appointed by Lord Grey's Government an assistant commissioner to inquire into the English poor-law system—a system which dated from the year 1601, in the reign of Elizabeth, and was entirely unsuited to the social conditions of the people of England in the early nineteenth century. In 1833 he was raised to the rank of a chief commissioner, and in the following year was appointed Secretary of the first Poor-Law Board. In this year there

was presented to Parliament the Report of the Poor-Law Commission, in the preparation of which Chadwick took the leading part. As a result of this Report, the Poor-Law Amendment Act was passed by Parliament in 1835. There was then evolved the system of Poor-Law Administration with which we are familiar at the present time, and which, being found, after some seventy years' experience, in many respects unsuitable to the needs of our twentieth-century civilisation, has now again been subjected to re-examination and revision at the hands of a Royal Commission.

In 1833 Chadwick was appointed a member of the Royal Commission on the Factory Acts, which initiated the appointment of Factory Inspectors under Government, and led to that comprehensive system of factory legislation for the protection of the workers from accidents, ill-health, and overwork, which is admittedly the most complete and enlightened system that any civilised state has as yet adopted.

It was also largely owing to Chadwick's researches, and his admirable powers of exposition, that the Government of the day was induced to make provision for the civil registration of births and deaths. Soon after the passing of the Act, in 1837, Dr. William Farr was appointed (in 1839) the Superintendent of Statistics under the Registrar-General. It is to this appointment of Dr. Farr that we owe those priceless statistical records of the Early- and Mid-Victorian periods that form the foundation of all our present knowledge of vital statistics in this country.

In 1839 the Poor-Law Commissioners were requested by Government to make an exhaustive inquiry into the health of the labouring classes in England and Wales outside the Metropolis. The Commissioners reported in 1842; and in the main this Report was the work of Chadwick,

as Secretary of the Commission. In 1843 Chadwick presented a Report on "Interments in Towns," which was a supplement to the report on the health of the labouring classes.

In the meantime the Government had appointed a further Commission—a Sanitary Commission—to inquire into the whole subject of the health of the nation, and this Commission was much aided in its work by Chadwick's advice and co-operation. The report of the Commission appeared in 1844.

In 1846 the Poor-Law Board, with which Chadwick had been associated since its inception, in 1832, as Assistant Commissioner, Chief Commissioner, and Secretary, was dissolved. In the following year, 1847, Chadwick was appointed on a Commission to inquire into the sanitary condition of the Metropolis; and in consequence of the report of this Commission in 1848, the first Board of Health was constituted—the members of the Board being Lord Carlisle, Lord Shaftesbury, Edwin Chadwick, and Dr. Southwood Smith. In this year Chadwick was made a C.B., and appointed a member of the Consolidated Commission of Sewers.

From this date Chadwick devoted all his time and energies to the work of the Board of Health. The Board's Report was completed and presented to Parliament in 1854, and the Board then passed out of existence, its place being taken by the Local Government Board. Chadwick's official life ceased in 1854, and he retired with a Government pension of £1,000 a year. He was made a K.C.B. in 1889, and died in his ninetieth year on July 5, 1890.

It is interesting to note that Chadwick was in favour of the separate system of sewerage for towns, and reported on this subject for the Government of India in 1871.

The influence exerted by Chadwick as a reformer in the spheres of poor-law, medical relief, sanitation, and education, can hardly be overestimated. He appeared at a time when the country was making enormous strides in commerce, manufactures, arts, and industries, but was too busy acquiring wealth to concern itself much with the social and sanitary requirements of its rapidly increasing artisan and labouring population. To Chadwick belongs the honour of being the foremost pioneer in the social and sanitary evolution of the labouring classes, which had its commencement in early Victorian times, the beneficial effects of which upon the happiness and prosperity of the nation are now abundantly recognised by all.

For further information as to the life and works of Edwin Chadwick, see "The Health of Nations—A Review of the Works of Edwin Chadwick," by Sir B. W. Richardson, M.D., F.R.S. (1887).

THE CAUSATION OF DISEASE BY EXCRETAL REFUSE

This short course of four lectures is complementary to the course already delivered by Mr. W. D. Scott-Moncrieff on the Engineering Aspects of Recent Advances in the Science and Art of Sewering. I assume at the outset that the term " Sewering " is to have a wide meaning, and to include considerations of the removal of excreta and other waste and refuse matters from houses and collections of houses (villages and towns), the conveyance of such matters in drains and sewers to the places where they are disposed of, and, finally, the means of disposal which are or can be adopted. In so considering the subject we are to be limited to its medical or hygienic aspects, that is to say, to the effects upon the health of the population concerned which are attributable to one or another system or method of removal or disposal.

For the past sixty or seventy years, and perhaps for longer, medical science has attributed importance as a factor in the production of disease to the retention of waste and refuse matters, and especially of human excreta, in or in the vicinity of inhabited dwellings. In the view of the older physicians these matters were prejudicial to health because they consisted largely of organic matters liable to putrefaction under appropriate conditions of warmth and moisture, and so produced offensive effluvia

and gases, which were regarded as the actual disturbers of health, when inhaled.

Such is still the view of some practitioners of medicine and of the general body of the lay public; and it is even now difficult to deny that offensive smells have no bearing on health, for the human body is so complex an organism, and so little is understood of the relationship between nervous phenomena and the bodily functions in health, that it is quite reasonable to suppose that, apart from their direct effects, the excitation of sensations of disgust produced by noxious smells may derange the delicate balance of normal secretion or excretion on which the maintenance of sound health depends. From the science of bacteriology we now know that the secreting surfaces of the mouth, upper air passages, and digestive system contain myriads of microbes, some species of which may be harmful, if there is a disturbance of normal conditions in their habitats; and just as grief, fright, or worry may upset the balance and be the originators of disease, so the possibility of physical phenomena, acting on the end organs of sense, playing a similar rôle in the economy cannot be excluded.

We know as a matter of experience that in susceptible persons offensive effluvia from drains, sewers, cesspools, privies, refuse heaps, manure-works, bone-works, or other places where concentrated organic vapours are evolved, very frequently produce nausea, vomiting, diarrhœa, and general gastric disturbance; and if such exciting causes of illness act for long periods, either continuously or with occasional intermittencies, it is quite possible that organic changes may be set up as the result of continued functional disturbances which eventuate in disease and ultimately in death.

Modern bacteriological research has shown us that in the production of disease, and especially of communicable and epidemic disease, more importance is to be attributed to the particulate matter—to the microbial contents—of excreta and animal refuse than to the foul gases generated by the putrefaction of the organic matters which such material contains. The waste matters given off from the human or animal body contain incalculable numbers of bacteria. These are present in the saliva and mucous excretions from the mouth, nose, throat, and air passages, in the sweat and epithelial débris from the skin, in the bowel discharges, and even in the urine, although the latter in health, when recently voided, is comparatively free from organisms. There is no very exact knowledge of what happens to these micro-organisms after the material in which they lodge is discharged from the body. A good deal must evidently depend on circumstance. The influences adverse to the life of those microbes that do not form spores are desiccation and oxidation from exposure to air and light, and the destructive action of the common saprophytic forms with which they have to compete in their new environment. It must always be borne in mind, however, that the vast majority of the organisms that reside in the waste matters of the body are associated with organic matters that may envelop them and protect them from adverse influences, such as heat, cold, light, oxidation, etc., and that they are not naked organisms, such as may be found in pure laboratory cultures, in dilute broth infusions, or other nutritive media.

These organisms, then—the characteristic organisms found in human or animal discharges in health—probably retain their vital activities and functions for a greater or less period after leaving the body. Occasionally these

organisms are associated with others, which are given off during certain disease processes. The disease organisms are probably even less resistant to adverse external influences than the organisms found in the healthy discharges; but even so, they may retain their virulent properties—their powers of infection—for a time sufficiently long to enable them to be reintroduced into the bodies of healthy but susceptible persons, and so continue the cycle of disease, which in its extreme form becomes an epidemic.

The dangers, then, to be apprehended from the retention of excretal matters in inhabited houses, or in their vicinity, are more especially concerned with the possibilities that exist that such matters may contain infective organisms. It will be impossible in this short course of lectures to discuss the *de novo* origin of infective disease by reason of the supposed acquisition of virulent properties by organisms which normally are nonpathogenic. To the majority of sanitarians it would appear that the *de novo* proposition is unproved, and that occurrences which in the past appeared inexplicable except on the hypothesis of a *de novo* origin, may now, in the light of our fuller knowledge, with greater likelihood be ascribed to the latent infection of "contact" or "carrier" cases, the existence of which was formerly unknown, or to the retention of infecting power by convalescents for periods of time not until recently considered possible.

The human diseases which are transmissible by means of the bowel or kidney discharges of man are Enteric Fever, Cholera, Dysentery, Diarrhœa, and the various intestinal parasitic worms. In the case of *Enteric Fever*, of which perhaps the etiological relations have been the most fully and carefully investigated of any of the specific infectious diseases, we now recognise that infection is

transmissible (*a*) by those who are actually suffering from a recognisable attack, typhoid bacilli being especially numerous in the stools during the second and third weeks of the illness; (*b*) by those who are suffering from an "ambulatory" type of the disease—the type that is mild, obscure, or unrecognisable clinically; (*c*) by those who are "contacts," i.e. those who have been infected, and who for a time pass *Bacillus typhosus* in their excreta, but are apparently not in any way affected in health thereby; (*d*) by those who are convalescent from the disease, but whose urine contains the specific bacilli, often in pure culture; and (*e*) by those probably very exceptional cases (less than 5 per cent. of the total [Savage] known as "chronic carrier" cases, in which an attack of enteric fever (mostly in women—about 75 per cent. of these cases being females) is succeeded by an indefinite period of latent infectivity lasting sometimes for many years, and due apparently to the discharge from time to time of virulent typhoid bacilli in the fæces for certain periods, such periods alternating with others when the discharges are free from infective organisms. The habitat of the typhoid bacilli in the body in these cases appears to be the gall-bladder; and Dr. Davies of Bristol has noted that in the cases investigated by him the months of May and June were those in which the bowel discharges of the "chronic carrier" resumed infectivity.

It is important to realise that in enteric fever the urine in the later stages of the illness and in convalescence may be more potent for mischief than the fæces, as in a certain proportion of cases of this disease, which, according to the recorded observations, may amount to some 20 per cent. of the total, the urine contains enormous numbers of *Bacilli typhosi*.

Inasmuch as the soiling of body- and bed-linen and of

water-closet seats and chamber utensils is much more readily effected by the urine than by the fæces, it is easy to understand how the hands of healthy persons may become infected by the handling of such objects; and, in consequence, how easy would be the transmission of infection in this manner, whilst the source of the mischief would in many instances be quite unrecognised.

Other diseases which are transmissible through the medium of the waste discharges of the body are: Diphtheria—by mucous excretions, crusts, and membranes from the throat, mouth, and nose; Scarlet Fever—by the same channels, and possibly also by the urine in cases of scarlatinal nephritis (the transmission of infection by the desquamating skin has been challenged, and must be regarded as doubtful); Measles, Whooping Cough, Influenza, and Pneumonia—by discharges from the throat and air-passages; Tuberculosis—by discharges from the lungs, kidneys, bowels, and ulcerating glands, in cases where these organs are specifically affected; various forms of septic inflammation due to discharges from various parts of the body similarly affected, or possibly due to filth of a specific character; but of this not much with certainty is known.

In regard to these various diseases, which are only exceptionally transmissible by the bowel discharges, it may be said that whilst proper methods of sewage removal and scavenging have their due share, no doubt, as agents in prophylaxis, yet the really important matter is destruction and disinfection of infective discharges as soon as they leave the body, and of all soiled articles of clothing, bedding, etc., and that we are only indirectly concerned with infectious diseases of this character under the heading of "Sewering." What does seem to be fairly well established as the result

of long experience is that, in houses or towns where there are faulty methods of scavenging and refuse-disposal, in some people, especially perhaps in children, a condition of low health (anæmia, debility, etc.) is fostered by reason of unhygienic conditions associated with such defects. The depressed state of health lowers the resisting powers of the body to attacks of disease due to microbial infection, and in consequence diseases of this nature are more prevalent and more fatal than they should be in hygienically well-ordered communities. Exact evidence of such a relationship between dirt and disease is not generally available; but that dirt and disease do stand in more or less direct relationship, few members of our profession will be prepared to deny.

In considering how non-removal, or faulty systems of removal of the waste matters of the body from houses and towns engender disease, we must examine somewhat closely, in the light of recently acquired knowledge, into the exact methods by which filth diseases of this character are spread. It will be convenient to treat of the subject under the following heads. 1. *Direct contact and conveyance of infection.* 2. *The mediate conveyance of infection by means of* (*a*) *vapours and gases*, (*b*) *dust and suspended matters in the air*, (*c*) *flies and other insects*, (*d*) *specifically polluted soil and water.*

Direct Contact and Conveyance of Infection

By this we mean that, owing to defective systems of collection and removal of excreta, an individual is brought into actual contact with such matters, that is to say, his hands, or other parts of his person, or his clothing are soiled with excreta, the infective material being thence

conveyed to his food or drink, or directly transmitted to his lips and mouth, by which portal it enters the body and originates disease. Such methods of infection, although probably much less common now than they were, when there was almost complete general ignorance as to the elementary principles of hygiene, may still be responsible for many more disease outbreaks than is commonly supposed. We have only to reflect on the inconceivable numbers of micro-organisms contained in the smallest droplet of mixed fæces and urine, of purulent discharge, or of mucopurulent expectoration, to realise that the transference of a fraction of such a droplet to the hands or body or clothes may be the means of infecting the food or drink with possibly virulent organisms in numbers sufficient to overpower the natural resisting powers of the body.

As we shall see later on, in the primitive conditions of society formerly prevailing in this country, and even now to be found in a modified degree in respect of the removal of refuse matters, infection by contact soiling must have played a considerable part in producing the endemic prevalences of disease that we read of in the accounts of those times. To contact infection may be ascribed the occurrence of cases of enteric fever amongst the nurses and attendants upon enteric patients, which even now happens occasionally in the most modern and best regulated hospitals, and which was of much more frequent occurrence in hospitals and infirmaries before the middle period of the nineteenth century. The experiences of military camps in our own armies during the South African war, and in the American armies during the Cuban war also do much to favour the view that contact infection quickly follows upon the aggregation of troops in confined spaces which are inefficiently cleansed and scavenged. Thus Dr. Childs,

in his paper on "Typhoid Fever Epidemics in the United States Volunteer Encampments in 1898," says that personal infection within the tent and from adjoining tents was an important if not the most important factor in the spread of the infection (*Epidemic Soc. Trans.* 1905–6). Similar evidence is forthcoming from the military commission which inquired into the diseases of the South African Field Force in the South African war (1900). "Contamination of boots, clothes, utensils, and hands at the latrines, or from ground near the latrine polluted with infected urine, probably assisted in a fair proportion of cases in spreading the disease (enteric fever), more especially in the later stages of the epidemic, when the ground was fouled."

Contact infection is also by no means uncommon in poor households where a case of unrecognised and unnotified enteric fever is being treated. Most medical officers of health will be able to recall instances of this nature even if they only amount to the occurrence of (secondary) cases of enteric in a house following upon a primary case of suspicious illness which was not isolated or properly nursed.

The facts in connection with the outbreaks of enteric fever at the Grove House Home for Girls, Brislington, near Bristol, in 1904, and at the Brentry Certified Inebriate Reformatory, Westbury-on-Trym, near Bristol, in 1906, recorded by D. S. Davies, M.D., and I. Walker Hall, M.D., in the *Proceedings of the Royal Society of Medicine, Epidemiological Section*, April 1908, tend to show with what facility milk and other foods may be infected by persons employed in kitchens or dairies whose bowel discharges contain *bacilli typhosi*.[1]

[1] See also Dr. Savage's paper on the "Bacteriology of Typhoid Fever," in *Public Health*, October 1907, and *Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government*

It is within my own experience also (some three years ago) that a cook in a boys' school, who was suffering from an acute attack of summer diarrhœa, was the means of infecting a large quantity of food which was being prepared for a school festival on the following day. In this outbreak the only feasible explanation appeared to be that the diarrhœa infection (probably the bacillus of Gaërtner) was transferred from the hands of the cook, after attending to the calls of nature, to the various dishes which were being prepared to be eaten cold on the occasion of the festival. The weather was warm at the time, and there may during the night have been some multiplication of the infecting organisms in the gelatinous or proteid constituents of the made dishes for the table; but, as a matter of fact, it was not possible to trace an infective quality to any one article of food in particular, as a very considerable proportion of the large numbers of people attacked with acute diarrhœa, as the result of partaking of the food supplied at the school, had eaten of a multiplicity of dishes. Possibly some of the outbreaks of so-called "ptomaine" poisoning, where it has not been possible to discover any such condition of the meat as would account for the development in it of poisonous activities after cooking, may be explicable on similar lines to the above; and where those engaged in food preparation are of really dirty habits, the possibilities of disease transference by direct contact are easily intelligible.

of India, New Series, No. 32, where the rôle played by "typhoid carriers" in disseminating enteric fever in India is very fully discussed by Lt.-Col. Semple and Capt. Greig, I.M.S. See also papers by Dr. Savage and by Dr. Archibald on "Typhoid Carriers," *Journ. Roy. San. Inst.* November 1908.

The Mediate Conveyance of Infection by Means of Gases

It was formerly considered by the greatest authorities in Public Health administration that the gases given off from excremental matter, and especially sewer gases, were oftentimes the means of propagating fever. When the late Sir George Buchanan wrote his admirable Reports for the Privy Council and Local Government Board, he was of opinion that the entry of air into houses from sewers which had become the receptacles for the excreta of enteric fever patients, was a sufficient explanation of subsequent outbreaks amongst the inmates. He writes of fever epidemics in Croydon, which could be indisputably associated with escape of sewer air into houses; and an epidemic in the same town in 1875 he attributed to the escape of infected sewer air from the small, ill-ventilated, pipe-sewers of the town through untrapped drains into the houses.

At Worthing outbreaks of enteric fever were attributed to the absence of any provision for ventilation of the town sewers, and the forcing up of sewer gases into houses through the traps of sinks and water-closets. That this was the cause of an outbreak in 1865 was evident to Buchanan, especially in view of the fact that the fever almost exclusively attacked well-to-do houses on the higher levels, where the water-closets were inside the houses, and almost entirely spared the houses, mostly of a much poorer sort, situated on lower levels, where the closet was placed outside the house. It was not so in the times of cesspools; then, these low-lying, poor houses were far more attacked with fever than the others. Moreover, as soon as openings were made into the sewers, the fever subsided from certain

houses where it had before maintained itself for months (*Ninth Report of the Medical Officer of the Privy Council*).

Other instances might be given of outbreaks of disease which were believed, on what was regarded as valid evidence at the time, to be due to escape of sewer gases into houses. Of recent years there have been few if any records of the association of enteric fever with sewer air. The investigations of Parry Laws and Andrewes in 1894 (*Report to the London County Council*) on the micro-organisms of sewage and sewer air tended to show that sewer air has but little ability to take up the bacteria present in the sewage with which it is in contact. The micro-organisms present in sewer air were said to be much more nearly related to those found in the outer atmosphere than to those existing in sewage. The *Bacillus coli communis* was very seldom found in sewer air, although present in sewage in numbers varying from 20,000 to 200,000 per cubic centimetre. Nor did it appear that sewage forms a favourable medium for the growth of *Bacillus typhosus*, which tends to die out in the course of a few days or a week or two, as the result of the sewer conditions which are unfavourable to its growth and continued activity.

More recent experiments by Major Horrocks, R.A.M.C., at Gibraltar (*Journ. Roy. San. Inst.* May 1907) gave results somewhat at variance with those obtained by Laws and Andrewes, for he found that specific bacteria present in sewage may be recovered from the air of drains and sewers, even when the sewage is flowing smoothly and without splashing. He concluded that specific bacteria present in sewage may be ejected into the air and carried by air currents through drains, sewers, and ventilation pipes, by (*a*) the bursting of bubbles at the surface of the sewage, (*b*) the separation of dried particles from the walls

of the sewers and pipes, and probably (*c*) by the ejection of minute droplets from flowing sewage. The influence of the bursting of bubbles of gas in a liquid and of splashing in disseminating into the air the micro-organisms contained in the liquid was demonstrated long previously by Professor E. Frankland (1871), and more recently by Haldane and Carnelly (*Proc. Roy. Soc.* 1887); and an actual outbreak of cholera in Southampton in 1866 was attributed by the late Professor E. A. Parkes to this very cause, namely, the passage of sewage infected with cholera evacuations, which had been recently pumped and was in a frothy and agitated condition, along an open conduit in the near neighbourhood of houses.

This outbreak of cholera is of special interest at the present time, when so much importance is being attributed to the conveyance of bacterial infections by means of minute droplets of fluid ejected into the air. The circumstances are as follows: On June 10, 1866, the P. and O. steamer *Poonah* arrived at Southampton from Alexandria, Malta, and Gibraltar, having on the preceding day lost a man from Asiatic cholera. Several of the firemen of the ship were suffering from acute diarrhœa, but were permitted to land, and dispersed themselves over the town. One of these men subsequently died of cholera. In the early part of July, some three to four weeks after the arrival of the *Poonah*, the outbreak of cholera commenced in Southampton, and some of the earliest cases occurred in several of the clean and airy houses near the pumping-station for the town sewage; whilst attacks of diarrhœa were found to prevail in some of the houses adjacent to those attacked by cholera. At that time in Southampton a great deal of the town's sewage from the outlying and low-lying districts was pumped up from the tributary sewers to be

discharged into the outfall sewer. Owing to cleansing operations in the sewers in June, the pumping had been discontinued, but it recommenced at the beginning of July, all the sewage which had accumulated in the western sewers being raised and discharged through an open conduit, some eight or nine feet long, into the outfall sewer. In this channel, when pumping recommenced, the sewage flowed like a cataract in a very frothy and agitated condition from the churning it had undergone, and the effluvia disengaged from this seething cataract of sewage were overpowering. The smell spread all over the neighbourhood, and was bitterly complained of by the inmates of the adjacent houses. It was in these houses that the early cases of cholera occurred. There was no other local cause, either in the sanitary arrangements of the houses or in their water supplies, to account for these cases of cholera; and Professor Parkes was of opinion that the principal cause of the outbreak was the discharge from the pumping-station into the air of fæcal effluvia from sewers into which cholera discharges had been largely introduced by the infected crew of the *Poonah*, and which had been retained in the sewers for several weeks owing to the suspension of the pumping for the purposes of cleansing.

Major Horrocks's results in respect of the bacteria present in sewer air have been confirmed by Dr. Andrewes (*Report of the Medical Officer L.G.B.* 1906–7), who writes that the view till recently current, that sewage does not readily give up its bacteria to sewer air, is shown to be incorrect. Under many ordinary circumstances characteristic sewage bacteria are to be found in the air of drains and sewers. Andrewes found that the streptococci of drain air correspond with those of sewage, and only to a slight extent with those found in fresh air. Similarly, the bacilli of the colon

group obtained from drain air correspond with those of sewage; fresh air contains practically no bacilli of this character. The bacteria derived from sewage probably form but a small proportion of the total bacterial flora present in sewer air, unless there is much splashing or agitation of the sewage in the vicinity. Still, they are liable to be present in drain and sewer air generally, even although their numbers are relatively small. Dr. Andrewes thinks that the failure to identify these organisms in sewer air in 1894 was due to the fact that the special selective media, which are now available for the cultivation of various classes of micro-organisms, were then unknown.

It would appear, then, that anything which causes agitation of the surface of the sewage in sewers or drains, such as splashing, or bursting of bubbles of gas in the liquid, is likely to eject minute droplets of fluid which will contain sewage bacteria. The same thing was shown by Dr. M. H. Gordon in respect of the minute droplets of saliva which are ejected from the mouth in coughing or loud talking. These droplets carry into the air some of the teeming bacteria present in the oral cavities of the persons who cough or talk in this manner (*Report on the Ventilation of the Debating Chamber of the House of Commons*).

It is reasonable to conclude that, in the past, too much importance has been attributed to sewer air and gases as a cause of disease, whilst at the present day there is a tendency to belittle unduly the pathogenicity of organic effluvia from middens, cesspools, drains, and sewers. It is, perhaps, too little realised how easily organisms of intestinal type may be disseminated into the air when the contents of middens, privies, or cesspools arc disturbed by the operations necessary for the removal of their contents, or how easily similar dissemination occurs in drains

receiving the water-closet discharges from the upper floors of a house through vertical soil-pipes. Even in large sewers there may be splashing and surface agitation of the sewage by means of drains discharging liquid near the crowns of the sewers, by the bursting of bubbles of gas whenever there are stagnation and sedimentary deposit, or by the movements of the rodents which infest, in large numbers, the sewers of all towns. This subject, however, will be further discussed when considering the subject of drain and sewer ventilation.

Mediate Infection by Dust and Suspended Matters in Air

In this country there is very little evidence that the desiccation of human excretal matter and its scattering into the air as dust is productive of harmful effects. At any rate, it is not usual for human excreta to be so deposited as to be submitted to such desiccating processes. Midden pits, privies, and cesspools, whatever their other sanitary shortcomings, maintain the excreta deposited therein in a moist condition, and prevent any dust formation. Even when night-soil is deposited on land for agricultural purposes, the humidity of the air and of the superficial layers of the soil are usually sufficient to prevent the drying of the deposited refuse to the extent required to form dust in any quantity. It may be otherwise in tropical or dry climates. Under the burning rays of a vertical sun human fæces are very quickly desiccated and pulverised, and the practice of indiscriminate defæcation pursued by the natives of some tropical countries may lead to the production of a dust of a distinctly dangerous character.

Firth in his work, "The Theory and Practice of Hygiene" (p. 162), writes: "Certainly in India there prevails a strong

opinion that not a little of the prevalent enteric is due to the local custom of disposing of sewage by superficial burial. This practice in dry seasons favours the dissemination of fæcally laden dust, which fouls air, water, and food. From our own experiences in tropical countries we are disposed to admit the legitimacy of this view."

Experiments have been made on the viability of the bacillus of enteric fever in soils which have been subjected to various degrees of drying, and these experiments may be summarised as follows: Firth and Horrocks (*Brit. Med. Journ.* September 27, 1902) showed that the enteric bacillus can be recovered up to the twenty-fifth day after inoculation from soil which has been allowed to become so dry as to be readily blown about as dust; and that the bacillus is able to survive in surface soil an exposure to 122 hours of direct sunshine, extending over a period of twenty-one consecutive days, the locality being Hampshire, England, and the season the months of June–July. In India, Aldridge (*Ind. Med. Gaz.* July 1903) recovered the enteric bacillus from earth fouled by the urine of patients suffering from typhoid bacilluria, on the first, fourth, and ninth days of drying; and in the same country W. S. and L. W. Harrison (*Journ. R.A.M.C.* vol. ii. p. 721) found that enteric bacilli survived in dust contaminated with infected urine for five days, and in the same dust exposed to the June sun of India for nearly three days, during seventeen hours of which the dust had been exposed, as indicated by a buried thermometer, to a temperature of 127° F (Firth: "Theory and Practice of Hygiene," 3rd edit. p. 414).[1]

[1] (See also "*Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India*" for Investigations on the Viability of the *Bacillus typhosus* outside the Human Body (Semple and Greig).

In the United States Volunteer Encampments in 1898 Childs considers that there can be no doubt that soil containing living typhoid bacilli was frequently conveyed on the boots and clothing of the men and in the form of dust by air currents into the tents, where the dust particles mingled with the food, bedding, and tentage. Infection was undoubtedly caused in this way to a considerable extent, but actual proof of such occurrences is almost impossible where camp pollution is general, and there are also other causative factors at work. In the South African campaign importance has been attributed as a cause of enteric fever in the camps to the dust storms which prevailed and to the foul nature of this dust, which to a certain extent was derived from the excreta deposited in the latrine trenches, there being in every camp men who were incubating and actually suffering from enterica.

The Commission appointed by the Secretary of State for War in 1900 to inquire into the enteric fever and dysentery occurring in the South African war reported that, under the exceptional circumstances of a very filthy camp, dust may have been a factor in the propagation of these diseases, but they did not think it played an important part.

It may also be mentioned that amongst British troops serving in India there is a considerable difference in the prevalence of enteric fever between the mounted troops and the infantry. Thus, for the period 1895–1907 inclusive, the admission rates per 1,000 of strength for this disease are infantry 20·3, cavalry 37·6. It is suggested that the cavalry horses foul the ground in the vicinity of the barracks, especially in the riding-schools, and that the accumulations of horse-manure favour the propagation of flies. As regards the part played by dust in the propagation of enteric fever, it is stated (*Lancet*, January 23, 1909) that at Umbala,

in April 1904, it was noted that the majority of the enteric cases admitted to hospital were going through a course of equitation, and the men complained very much of the clouds of dust in the riding-school, many attributing their illness to this cause. After the abandonment of the riding-school and the use of the open country for training the men, very few cases occurred.

Waldo and others have endeavoured to show a relationship between dusty, because defectively scavenged, streets in towns and an undue prevalence of summer diarrhœa. The evidence of such a relationship is not, however, very conclusive; and, in any case, the dust arising from the streets is chiefly desiccated horse-manure, and not markedly associated with human refuse matters.

There is, then, a good deal of experimental evidence as to the possible infectivity of the dust which may be derived from desiccated and pulverised excreta; but there is not much evidence of actual transmission of disease by this means alone. However it may be in tropical countries, in temperate climates it is probable that other modes of disease-transmission are of far more frequent occurrence than that by infected dust.

The Conveyance of Infection by Flies and other Insects

That flies should be the means of conveying infection from excretal matters to the food of man seems highly probable when we know that these insects do actually convey particles of excreta on their feet after settling on such matters, and that their habits lead them to visit indiscriminately refuse matters, the food, and the bodies and faces of men. It has been shown that micro-organisms

of intestinal type can be grown on nutrient media which have been exposed for flies to alight upon, if the flies have had access to excreta in the vicinity (Copeman, *Proc. Roy. Soc.* 1890; Horrocks and Firth, *Brit. Med. Journ.* 1902).

That enteric fever or diarrhœa has been actually spread in this way is not easily capable of proof, because there are usually other possible causative factors at work which complicate the issue. Thus Childs in his account of the typhoid epidemics in the U. S. volunteer encampments, previously alluded to, writes: "There is every reason for concluding that typhoid germs must constantly have been conveyed by flies from the latrines to the mess-tents and food. Hosts of flies swarmed about the latrines, visiting alternately the fæces and the mess-tents. In some instances, where lime had been sprinkled over the contents of the latrines, flies were to be seen with their feet whitened crawling over the food." The military commission on enteric fever and dysentery in the South African war was of opinion that flies played an important part in propagating these diseases amongst the troops by conveying infection from infected latrines to food and drink.

Sir Alfred Keogh, Director-General of the Army Medical Service, in an address on "The Results of Sanitation in the Efficiency of Armies in Peace and War," delivered to the Royal Sanitary Institute (*Journ. Roy. San. Inst.* February 1909), says: "The conservancy methods in use in cantonments in India consist of a pail-and-cart removal system, combined with the use of dry earth as a deodorant, the details of the system, on which its success depends, being left to the care and attention of the two most careless individuals on earth—the uninstructed British private and the native sweeper. The opportunities afforded by the carelessness of men were boldly seized upon by the all-

pervading fly. By the energy of this enterprising insect, filth was rapidly and unostentatiously conveyed from the latrine to the dining-room, and any existing focus of infection given every opportunity of widening its area. In the past two or three years particular attention has been paid to the agency of infected latrines and flies as causes of enteric fever, and it is to this attention that, in the opinion of the majority of the sanitary officers having practical experience of enteric fever in India, the diminution in this disease during the last few years has been due. The latrine as the source, and the fly as a potent means of dissemination of the poison existing there, will always attract the chief attention of the practical sanitarian."

There are thirty-six species of fly which lay their eggs in human excreta, including *Musca domestica*, the common house-fly. Most of these flies prefer horse-manure as a breeding place, yet, when human excrement is left exposed, they will breed in it in large numbers; and, in India, in the latrine trenches of the military cantonments, it is a common experience in the fly season to find enormous numbers of larvæ, pupæ, and young flies on turning over the earth in the trenches, showing that the majority of the flies in cantonments are hatched there.

In the *Brit. Med. Journ.* October 17, 1908, Dr. Klein reports that he was able to cultivate typical enteric fever bacilli from the bodies of a number of flies which were caught in houses invaded by this disease. After the occurrence of a case of enteric fever in a house forming one of a row, a number of typhoid cases made their appearance in the neighbouring houses. All known channels for transmission of the disease, *e.g.* personal contact, polluted water or milk, or defective drains, could be excluded. The only condition likely to have any bearing on the question

of transmission which was common to all the houses of the row, was that they were swarming with flies.

Hamer, Niven, Nash, and others have written upon this subject of disease convection by flies, especially in connection with summer diarrhœa prevalence; and whilst we can well conclude that such occurrences do occur, and probably with some frequency, complete proof is, in the nature of things, largely wanting. The coincidence of the rise in summer diarrhœal mortality with a rapid increase in the number of flies in houses and towns, although highly suggestive of a causative relationship, is equally explicable on the ground that both are due to the rising air-temperatures, and are therefore seasonal occurrences with no necessary interdependence.

The Conveyance of Infection by Specifically Infected Soil

In considering this subject we must carefully distinguish between pollution of the surface soil and of the subsoil below the surface.

Specific Pollution of the Surface Soil.—Numerous experiments have been made on the viability of the *Bacillus typhosus* in different kinds of surface soil—sterilised and unsterilised. The earlier work of John Robertson and of Sidney Martin (*Loc. Gov. Bd. Repts.* 1896–9) was of extreme value, but is not altogether in accord with more recent investigations; and this is not surprising considering the great difficulties in recovering the specific bacillus from soil crowded with myriads of other organisms, some of which are very much allied in type and in morphological and cultural characteristics to those indicative of the true enteric bacillus. For present purposes reference need

only be made to the classical researches of Firth and Horrocks in 1902 already alluded to. The authors showed (1) that the enteric bacillus does not display any ability either to increase in numbers or grow circumferentially in soil. (2) That it is able to assume a vegetative existence in ordinary soil and in sewage-polluted soil, and to survive therein for varying periods, amounting in some cases to as much as seventy-four days. (3) That the presence or absence of organic nutritive material in the soil appears to be a largely negligible factor, since the enteric bacillus can survive in either a virgin soil or in an organically polluted soil. (4) That in fine dry sand the bacillus survives some twenty-four days, but that from similar sand kept moist with either rain or dilute sewage, the organism disappears about the twelfth day, probably owing to its being washed down into deeper layers. (5) That in peat the bacillus dies out in thirteen days. (6) That in a sewage-polluted soil, obtained from beneath a broken drain, the bacillus was able to survive for sixty-five days ; whilst in ordinary soil moistened occasionally with dilute sterile sewage the micro-organism was recoverable up to the seventy-fourth day.

The above results are highly suggestive of the dangerous possibilities inherent in excretally polluted surface soils. The contamination of the ground surface around habitations with excrementitious matters, which is so frequently seen in the poorer classes of urban and rural dwellings, must, in the light of Firth's and Horrocks's work, be a frequent source of disease, and should induce sanitary authorities to require the paving of all yards and areas around dwellings with impermeable surfaces laid with gradients and drainage adequate to carry all surface waters rapidly away to the drains and sewers. Having regard also to these experi-

ments, the practice, so prevalent in rural districts, of burying typhoid excreta in the top soil of the cottage garden is not one to be encouraged, more especially if there is any risk of the typhoid organisms being washed by rain through the surface soil into water-bearing strata beneath.

Specific Pollution of the Subsoil.—There can be no doubt whatever that the subsoil is frequently polluted by the passage of sewage and excremental filth out of leaking drains, sewers, cesspools, middens, and privies. The ground air and the ground water are both polluted in this way; and, as is now universally recognised, subsoil pollution with sewage is the most frequent cause of shallow-well contamination with which we are acquainted.

The question, however, of whether a polluted ground air can originate disease has never been satisfactorily determined. We know that with a rise in the level of the subsoil water the top layers of the ground air will be very slowly compelled to escape at the surface of the ground; and such escapes may take place in the ground covered by habitations which have no layer of cement, concrete, or other impermeable material covering their sites. We know also that evaporation of moisture goes on from the top layer of the ground water, that the ascensional force of the evaporating water may conceivably carry up with it the microbes contained in the air occupying the interstices of the soil above the ground water-level, and that in this way micro-organisms residing in the soil under a house may be drawn into its interior.

It was formerly believed that there was some causal relationship between occurrences of enteric fever, of diarrhœa, and of diphtheria and movements of the ground air, specific pollution of the subsoil being presupposed.

Thus Pettenkofer showed the existence of a relation between the height of the ground water in the porous sandy soil of Munich, and epidemic outbreaks of enteric fever. When the water in the shallow city wells was at its lowest level, especially after a rapid fall succeeding an unusually high level, the disease was most prevalent in the city. The same thing was observed in cholera outbreaks; and it was considered either that the expulsion of ground air into the houses consequent on the rapid rise of the subsoil water, or the evaporation of moisture from the drying subsoil, subsequent to the sinking of the water-level, were the efficient causes of the outbreaks with which these conditions were associated.

Very similar theories have been enunciated by Adams in connection with diphtheria prevalences at Maidstone (*Proc. Eighth Internat. Cong. of Hygiene*, 1894), and by Newsholme (*Epidemic Diphtheria*, 1898). Newsholme holds that the epidemic prevalences of diphtheria, of enteric fever, of erysipelas, of scarlet fever, and of rheumatic fever are favoured by deficient rainfall, if this is sufficiently long continued; and that the organisms of these diseases have a saprophytic phase as well as a parasitic, the saprophytic stage being passed in the soil. Conditions which tend to raise the level of the ground water also tend to drive the micro-organisms out of the soil, which on transplantation into the human body reassume their parasitic properties.

Exact observation, we believe, has never yet been made as to any actual passage of micro-organisms out of the ground with the ground air; and considering the extreme slowness with which ground air must as a rule be evolved, owing to the rise of the water-level being usually a very gradual process, and having regard also to the fact that the micro-organisms in the soil would naturally tend to

adhere to the damp surfaces on which they are deposited, and that the ground in this country, even close to the surface, always retains a considerable degree of humidity, it does not seem *a priori* at all likely that specific microbes which have reached the subsoil are ever evolved again on the ground surface.

It is true that most observers are agreed that for houses to be built on "made" ground containing rubbish and human refuse is bad for the health of the future occupiers, and that diphtheria and scarlet fever are more prevalent amongst the dwellers in such houses than in those built on virgin soil. That there are soil emanations, and that the emanations from polluted soil are inimical to health is agreed; but that such emanations have ever, *per se*, originated outbreaks of infectious disease has still to be proved. Ballard held that organically polluted conditions of soil and subsoil were especially favourable to summer diarrhœa, and this is undoubtedly correct; but evidence as to any micro-organism, which may be thought of as causative of this disease, actually residing in the soil, either in a saprophytic or parasitic stage, and leaving the soil on the advent of hot weather to infect the food or intimate belongings of the occupiers of houses, is still wanting.

On the whole, then, we may rightly conclude that great as are the possibilities of disease transmission by surface pollution of the ground around habitations, the pollution of the subsoil by excrementitious matters is only a matter of importance, if there is a possibility of subsoil-water contamination, or if there is any risk of such filth again reaching the surface of the ground by soakage into cellars or basements or other places accessible to human beings.

Conveyance of Infection by Specifically Polluted Water

Enteric fever in this country, on the continent of Europe, and in the United States of America, is so frequently conveyed by means of polluted water, and so much is already known of this method of infection, that we need not delay long in considering this method of transmission of disease.

We know that wells are very commonly polluted by the passage of excretal liquids through the soil from defective drains or cesspools into the water supplying the well. The observations of Firth and Horrocks on the viability of the *Bacillus typhosus* (already quoted), when implanted in soils of different kinds, are of much interest in this connection. If, as their experiments seem to show, the specific bacillus can survive in soil, whether virgin or polluted, for several weeks, and can be washed down into the subsoil by rain or liquids from drains and cesspools, without losing its vitality, it is evident that the question of whether a well is liable to pollution is not so much a matter of the time taken for the polluting material to pass from its source —the leaking drain or cesspool—into the water of the well, as of the kind of filtration the polluting material is subjected to in its passage through the soil, and whether this filtration is of so searching and thorough a character as to arrest the living microbes in the same way that a sterilising filter does.

Inasmuch as water is sometimes fouled, not by percolation of polluting liquids through the ground, but by direct passage of cesspool liquids or midden contents or sewage from drains and sewers into streams and water courses, it is very evident that it is desirable to know how

long the specific bacilli of enteric fever, cholera, etc., can survive in such matters after leaving the body, and also in the water to which they may subsequently be introduced.

Dr. Sims Woodhead in his evidence (13,103) before the *Royal Commission on Metropolitan Water Supply* (1893) stated that in those experiments in which the most confidence can be placed it was shown that fifteen days or thereabouts is the extreme limit of time during which the typhoid bacillus can maintain its life, subsequent to its introduction into river water. In water diluted with sewage the period is shorter, and in fæcal matter probably shorter still. Professor Ray Lankester stated that the typhoid bacillus will retain some kind of vitality for three months in water which is devoid of other organisms, but disappears much sooner in water in which other harmless species of aquatic bacteria are actively growing.

In 1894 Parry Laws and Andrewes, in their investigation of the micro-organisms of sewage for the London County Council, wrote that their experiments must be regarded as incomplete, and as affording only an indication of the probable fate of typhoid bacilli which gain access in a living condition to sewage. They were of opinion, however, that sewage does not form a medium in which much, if any, growth is possible for them under natural conditions, and their death is probably only a matter of a few days, or at most one or two weeks. They say, however, this degree of resistance may be sufficient to allow of their being carried in sewage to remote distances, and of their being able to produce disastrous results should they gain access to any water supply.

More recently Dr. A. MacConkey made some experiments on the longevity of the *Bacillus typhosus* in sewage and

sewage effluents for the *Royal Commission on Disposal of Sewage* (*Second Report*, 1902). When crude sewage was inoculated with the *B. typhosus*, in one experiment the organism was recovered up to the thirteenth day after inoculation, but in a second experiment was not recovered on the sixth day. Dr. MacConkey thinks that the *B. typhosus* does not multiply, but dies more or less rapidly in crude sewage. Semple and Greig in their Report to the Government of India already quoted show that in that country the life of the *B. typhosus* is limited in urine to about three days, and in fæces to about four days after evacuation from the body, even although in each case the typhoid organism was practically in pure culture.

Dr. Houston has recently (May, 1908) presented a Report to the Metropolitan Water Board on "*The Vitality of the Typhoid Bacillus in Artificially Infected Samples of Raw Thames, Lee, and New River Water, with Special Reference to the Question of Storage.*" Samples of these raw river waters were inoculated with typhoid bacilli in the proportions of forty bacilli per c.c. of water, 170,000 per c.c., 470,000 per c.c., 475,000 per c.c., 525,000 per c.c., and 8,000,000 per c.c. Some of the strains of typhoid bacilli used in the experiments had been isolated quite recently from typhoid patients, and none of them were old stock laboratory cultures. The samples of infected water were stored in the laboratory. As the result of this storage, an immense decline in the number of typhoid bacilli was noticed at the end of the first week. Thus, no bacilli were found in the waters inoculated with only forty bacilli per c.c., whilst the percentage reduction in the case of the samples inoculated with the very much larger numbers of bacilli varied from 99·7 to 99·9 per cent. These results were, however, obtained by using only one particular medium for deter-

mining the initial number of typhoid bacilli added to the samples, and for estimating the numbers still surviving at the end of the week, the experiments ceasing when none could be found in 1 c.c. of the sample.

When, however, a variety of methods and of media were employed in the identification of the typhoid bacilli, so as to make as certain as possible that the bacillus would be isolated, if it were still alive, and using 100 c.c. of the infected water, instead of 1 c.c. as the basis of determination, then the following very important results bearing upon the final disappearance of the bacilli from the stored waters were obtained :

In none out of the total of eighteen experiments were negative results obtained in one, two, three, or even four weeks.

In four out of the eighteen experiments negative results were obtained in five weeks (= 22 per cent.).

In seven out of the eighteen experiments negative results were obtained in six weeks (= 39 per cent.).

In eleven out of the eighteen experiments negative results were obtained in seven weeks (= 61 per cent.).

In sixteen out of the eighteen experiments negative results were obtained in eight weeks (= 89 per cent.).

In all the eighteen experiments negative results were obtained in nine weeks.

It is evident, then, from these very careful experiments, that, if the not unreasonably large amount of 100 c.c. of the water be taken for examination, the final disappearance of typhoid bacilli from an artificially infected raw river water may not take place until nine weeks after inoculation. What bearing these facts have upon the actual, as opposed to the artificial, infections of streams, and upon the natural processes of elimination of such infecting agents from

streams, rivers, and reservoirs, as opposed to what occurs upon storage under laboratory conditions, it is, of course, impossible to say; but they at any rate strengthen the position of those who affirm that there is *no evidence of any rapid and final disappearance of the enteric fever infection in polluted waters under natural conditions*, and that *safety lies in the assumption that such final disappearance within a few days of infection cannot be relied upon.*

In the same Report, Dr. Houston reviews the work of Professors Jordan, Russell, and Zeit on the longevity of the typhoid bacillus in water, which was carried out in America in the autumn of 1903. These experiments were performed under conditions which sought to imitate closely natural as opposed to artificial (laboratory) conditions. The distinctive features of the majority of these experiments were that the typhoid-infected water was enclosed in permeable sacs (colloidin and parchment) submerged in flowing river-water or in lake-water, so as to allow of the diffusion of bacterial excretion products, and generally to permit of dialysable substances in water, either inside or outside the sacs, to pass in or out.

The conclusions of Professors Jordan, Russell, and Zeit were: (1) That under the conditions of the experiments, which probably closely simulate those in nature, the vast majority of typhoid bacilli introduced into the several waters studied, perished within three or four days.

(2) It is theoretically possible that specially resistant cells may occur which are able to withstand for a longer period the hostile influences evidently present in water. Our experiments, however, show that, if such resistant individuals exist, they must be very few in number, and constitute only a small fraction of the bacilli originally entering the water.

Dr. Houston's comments on these conclusions are of extreme significance. He writes: "Personally I think that in conclusion No. 2, the words 'theoretically possible' should perhaps be replaced by the words 'almost certain,' and that the word 'much' should precede the word 'longer.'" The paragraph would then read "It is almost certain that specially resistant cells may occur which are able to withstand for a much longer period the hostile influences evidently present in water." Further, Dr. Houston says, the "specially resistant individuals" referred to may, possibly, be *relatively* more numerous in typhoid excreta than in artificial cultures. The significance of this observation, of course, lies in the fact that the pollutions of water which cause outbreaks of disease are due to typhoid excreta and not to artificial cultures of the *B. typhosus*.

From Dr. Houston's *Second Report on Research Work for the Metropolitan Water Board* it appears that negative results have invariably been obtained from the examination of large numbers of samples of raw Thames, Lee, and New River water for the presence of the typhoid bacillus. These experiments were carried out during the twelve months ended July 31, 1908, weekly samples being taken from the Thames, Lee, and New River respectively—total 156 samples.

Dr. Houston writing on the above says: "All that can at present safely be affirmed is that the most recent tests for *B. typhosus*, applied to a considerable volume of raw river water, at weekly intervals, during a period of twelve months, and involving the study of 7,329 microbes, failed to reveal the presence of a single typhoid bacillus. It would, however, be altogether presumptuous to infer from these observations that the typhoid bacillus

is never present in the raw river waters, or to conclude that any relaxation in the processes of purifying the raw waters by storage and filtration before delivery to the consumer is justifiable. It is proposed to continue the experiments, and to work with a much larger volume of raw river water, using a centrifugal apparatus specially made for the purpose. When these further experiments have been completed, it may be possible to speak more definitely on this subject."

From the epidemiological point of view, the fact that the great majority of the typhoid bacilli introduced into a natural (unsterilised) water disappear in a few days, is of less importance than the fact that there are a few "specially resistant individuals" that survive. Further experimental work is now more especially needed to ascertain, if possible, whether the typhoid organism may not assume a vegetative or saprophytic form after leaving the human body, and whilst, on the one hand, undergoing loss of virulence, become capable, on the other, of resisting external agencies, such as light, oxidation, and competition with other bacterial saprophytes which are inimical to its continued existence in a parasitic form. The "very few" typhoid bacilli in Houston's and in Jordan, Russell, and Zeit's experiments, which remained alive for a month or two, after the disappearance of all their associates within a week of the inoculation of the water, is somewhat suggestive of the "very few" survivors having exchanged a parasitic for a vegetative or saprophytic existence.

If such saprophytism of the parasitic organism does occur, can the saprophyte on reintroduction into the human body resume its virulence and be the cause of an attack of enteric fever? These are interesting questions, more especially in relation to the reason why enteric fever

and cholera are largely endemic diseases—endemic in certain areas of favourable environment, with capabilities of epidemic extension under suitable climatic or other conditions.

Experience shows that Asiatic cholera which has been introduced into a European community during the autumn, is able to maintain itself during the winter and spring and assume epidemic proportions again with the summer. It is possible, of course, that the infection is maintained by means of mild sporadic cases during the cold months of the year; but it is also possible that the cholera vibrio can survive in a saprophytic form in water and soil during the cold season, retaining its capacity for renewal of virulence with the setting in of hot weather.

In this connection it is well to recollect that a disease so closely simulating enteric fever, as to be clinically indistinguishable from it, is ascribed to a micro-organism, or rather to a class of micro-organisms, which have been named *Bacilli paratyphosi.* The latter can be distinguished culturally from the true *B. typhosus*, and have, in fact, cultural characteristics which seem to place them generically between the true *B. typhosus* and the *B. coli communis*—the whole group of colon organisms presenting certain common features which seem to indicate a family relationship. The disease due to paratyphoid organisms is only, perhaps, occasionally seen in Europe and temperate countries, and appears to be even less frequent in India, but in South Africa it is relatively more often met with. Thus, in the *Report of the Army Medical Department* for 1907 it is stated that in India, out of a very large number of examinations of blood, fæces, and urine from typhoid cases made at the Central Research Institute, in only six were paratyphoid bacilli found.

Of these, four were *B. paratyphosus* "A" (Brion-Kayer), and two were *B. paratyphosus* "B" (Schotmüller). This proportion differs from what has been found in Europe, where the paratyphoid organism is far more common; but it tends to indicate that the great majority of typhoid infections in British troops in India are due to the *B. typhosus.*

In South Africa, on the other hand, amongst the British troops stationed there in 1907 it would appear that about 20 per cent. of the typhoid cases might be due to organisms of the typhoid colon group (paratyphoid, colon bacillus, and unclassified forms) other than the true *B. typhosus.* It is possibly due to the presence of a relatively large number of these atypical and mild cases that the proportion of deaths to attacks of enteric fever in South Africa is comparatively low.

What the exact relationship is between the true *Bacillus typhosus* and the paratyphoid group; whether, under any circumstances, outside the human body there can be a change of type of *B. typhosus* into a paratyphoid organism and ultimate reversion to the *B. coli communis*, with partial or complete loss of parasiticism, are questions which do not at present admit of any answer. The mere fact, however, that enteric fever is not always dependent on a special micro-organism, but can be apparently produced by an allied group of organisms, capable of differentiation by appropriate cultural tests, is highly suggestive of those possibilities of variation, modification, and reversion in type under differing environments of host, soil, and climate, which are consistent with the natural laws of evolution of species.

Smallman's experiments with guinea-pigs (*Journ. Roy Army Med. Corps*, vol. v.) suggest that in the lower animals

there may possibly at times be a transformation of the *B. typhosus* into the *B. paratyphosus*, for after injecting into the peritoneal cavities of 200 guinea-pigs pure cultures of living and dead enteric bacilli, in 22, or 11 per cent., the organisms found after death were of the paratyphoid type, and not true *B. typhosi.*

What relation such transformation of enteric bacilli in the lower animals has to the etiology of the human enteric fever is unknown, but is evidently a subject for further inquiry.

The whole subject of the pathogenic relations of the paratyphoid group of organisms is still, however, unsettled. Conradi and other observers assert that this group—the paratyphoid—are widely distributed in nature, and may be found in many articles of food, as well as in the urine and solid excreta of healthy persons and healthy animals. If this is a general truth, the presence of paratyphoid bacilli in Smallman's guinea-pigs, and even their presence in the excreta of patients presenting all the symptoms of enteric fever may be a matter of no significance, so far as the causation of disease is concerned. In respect of the bacillus of hog cholera, one of the group of paratyphoid organisms—until recently regarded as the specific organism of this disease of pigs—Salmon, the American bacteriologist, has shown that although found in the excreta and in the blood of pigs affected with cholera, it is not really the causal organism, as the blood of a pig affected with the disease, if filtered through porcelain, so as to be quite free from all micro-organisms detectable under the highest powers of the microscope, is still capable of infecting healthy pigs on inoculation. Such a result, obtained by so eminent a bacteriologist, suggests reflections as to the possibility of other diseases, now regarded as being due to recognised

specific organisms, being possibly due to unidentified microbes, so small as to be invisible under the highest powers of the microscope, and so minute as to be capable of traversing the pores of the finest porcelain filters. The whole subject is again coming into prominence owing to the alleged production of disease in man by the bacilli of some of the viri now in use for the destruction of rats and mice, such bacilli belonging to the paratyphoid group, and being closely allied to the *B. enteritidis* of Gaërtner.

Reverting again to the subject of enteric fever and its specific organism, practical experience in numerous typhoid fever epidemics would seem to indicate that, as a matter of fact, no definite time can be assigned to the life of the enteric fever organism, or to its infectivity, when transferred from the human body to sewage, to soil, or to water. Under certain conditions it is quite possible that the life of the organism is a short one in its new surroundings; but there are so many other factors affecting its life, and possibly even its capacity for growth, inherent to sewage, soil, and water, with which we are unacquainted, that dogmatic statements on either side are quite unwarranted. Sewage, soil, and water are complex matters, with very varying physical and chemical constitutions, with biological characteristics little understood, and existing in nature under climatic conditions which are varying from day to day, as well as from season to season.

So much, at any rate, may be surmised from the teachings of epidemiology, that whilst sporadic or localised outbreaks of disease may be due to contact and direct infection, to dust, to flies, and possibly to sewer or drain air and emanations from contaminated soil, the epidemic form of the disease which attacks a number of households within a limited period of time, is due to water pollution, or milk

contamination by means of polluted water, or to shell-fish contamination by infected sewage.

The Relation of Septic Diseases to Excretal Filth

So far, in considering the question of disease causation by the imperfect removal and disposal of excreta, we have intentionally rather limited the survey to the single field of enteric fever outbreaks originating in this manner, this being the disease which is more especially connected with defective sanitation, and of which the etiological relations have been most fully investigated. It must not, however, be supposed that enteric fever and its allies—cholera and diarrhœa—are the only diseases with which sanitary science is concerned. Direct evidence of other diseases being dependent upon, or being favoured by, defective methods of scavenging or drainage, is very difficult to obtain; but if we have regard to the whole field of sanitary effort in this country in the past fifty years, we find that not only has the special death-rate of the country from enteric fever and cholera undergone an enormous diminution in that period, as the result of the improvements in water-supply, drainage, and sewerage, which have been of an almost national character, but also that the general death-rate has fallen, if not in a corresponding degree, at any rate in most substantial fashion; and it is only reasonable to suppose that in some measure, at any rate, the reduction in the general mortality depends upon the same causes that have so greatly influenced the enteric fever and cholera death-rates.

A comparison of mortality figures for specified diseases, as causing morbidity now and fifty years ago, is liable to lead to error, owing to the changes in nomenclature that

have occurred, and to the greater precision in modern diagnosis, which have caused the transference of many diseases from one group to another, as medical knowledge has slowly advanced, and greater exactitude in the certification of causes of death has been obtained.

There is, however, one group of diseases which may be specially mentioned as having a certain defined relation with the insanitary surroundings associated with retention of excretal filth, namely, the diseases which are classed as SEPTIC, and which are dependent upon the entrance of various species of septic micro-organisms into the human body. The better known of these diseases are Pyæmia, Septicæmia, Erysipelas, Phagedæna, Phlegmonous Abscess, to name the more serious and fatal ones, and Lymphangitis, Lymphatic Abscess, Boils, Carbuncles, Ulcers, septic forms of sore throat, etc., to name the more common, but less serious complaints. The more serious and fatal diseases of this class were at one time prevalent in hospitals and infirmaries as complications of surgical injuries and operation-wounds, but are now happily almost extinct in the modern well-managed hospital or infirmary. No doubt, aseptic surgery and modern methods of nursing have been the chief factors in the eradication of the septic sequelæ of wounds and injuries; but it must also be remembered that the drainage and sanitary arrangements of nearly all institutions for the sick were, up to thirty years ago, what we should now consider very defective; and it cannot be denied that insanitary surroundings must have played a part—and perhaps no inconsiderable part—in the production of sepsis, or at any rate of susceptibility to septic influences amongst the patients and attendants on the sick. Puerperal fever—the septicæmia attacking the recently confined woman—is another instance

of a disease which has notably diminished as sanitary enlightenment has advanced; and its connection with insanitary surroundings is of a similar nature to those appertaining to the septic infections of the general sick ward.

The minor septic diseases exhibit, perhaps, less obvious dependence upon insanitary surroundings; but septic sore throats are very commonly found to be associated with the breathing of foul air from drains and cesspools, and many minor forms of "blood poisoning" are apparently attributable to similar causes.

The bacteriology of raw or crude sewage shows that it contains enormous numbers of micro-organisms of a great many different species, of which the best known, because the most studied, are (1) *B. coli communis*, *B. Proteus*, and other gas-forming bacteria; (2) *B. enteritidis sporogenes*; (3) *Streptococci*, with which are occasionally associated *Staphylococci pyogenes*.

B. coli—an ærobic microbe—is of importance not only because of its numbers—usually at least 100,000 per c.c. of sewage—but because certain strains of the bacillus are distinctly pathogenic on inoculation into the lower animals (rodents), and there is evidence that the organism may play a rôle in the causation of human diseases, more especially in certain local infections of the kidneys, bladder, colon, and other abdominal organs.

B. enteritidis sporogenes is an anærobic organism, and exists in sewage in the form of spores, usually to the extent of at least 100 per c.c. Cultures of this organism may be, and often are, extremely virulent to guinea-pigs; and, further, according to Klein, certain epidemics of acute diarrhœa in man were found to be causally related to this organism.

According to Houston (*Second Report*, *Royal Commission on Sewage Discharge*, p. 25), the pathogenicity of sewage *streptococci* does not appear to have been established; but, then, virulent *streptococci* are well known to rapidly lose their pathogenic action when separated from the animal body and cultivated on artificial media. They are usually present in sewage to the extent of 1,000 per c.c., and their special interest is that they are evidently closely allied to the species that cause septic infections in man and animals.

Houston's work for the same Royal Commission (*Second Report*, p. 45) on the results of the subcutaneous inoculation of animals with crude sewage shows that the injection of London crude sewage into guinea-pigs (about 1 to 3 c.c. per 200 grms. weight) nearly always produced a local reaction, and not uncommonly death in from twenty-four to seventy-two hours. If a fatal result did not occur within a few days, occasionally the animal died after the lapse of some weeks from pseudo-tuberculosis. When the animal died rapidly, virulent microbes of the *B. coli* and *B. proteus* class could be readily isolated from the blood or tissues. If the sewage before inoculation was sterilised by heat or filtration, no pathogenic results followed, showing that it is the microbial contents of the sewage, and not the chemical products of their activity in sewage, which set up disease in rodents.

These experiments, of course, do not establish the pathogenicity of sewage in relation to man, when introduced by the ordinary channels of entrance—the mouth and air passages. But in respect of the septic diseases, now under consideration, it must be remembered that the portal of entry of the poison is some open wound or skin lesion, and it is quite possible that the results of inoculation in man by open wounds or skin lesions are similar in character to

those displayed by the lower animals, the chief differences being due to the disproportions in dosage, having regard to the different bodily weights of man and rodents. There can, indeed, be very little doubt that many of the organisms contained in human excreta are capable of producing septic infections in man if inoculated through a breach of surface, even although their capacities for mischief when swallowed with food or drink have not yet been ascertained with any approach to certainty.

Modes of Infection

In this connection it is interesting to note that importance is now being attributed to the digestive tract as the possible point of entrance of infective poisons into the human body. In respect of pulmonary tuberculosis, which was at one time almost universally regarded as contracted by inhalation of the bacilli of tubercle into the air cells of the lungs, Sir William Whitla, in the Cavendish Lectures (*Lancet*, July 18, 1908), said, "It appears to be conclusively proved that the alimentary tract is a frequent portal of entry for the tubercle bacillus, which is able to pass through the intact mucous membrane of the bowel without producing any local lesion at the point of entrance, and this event is especially frequent in children. Probably at no distant date the contention of Calmette will be accepted, that in the immense majority of cases pulmonary tuberculosis is not contracted by inhalation, but, as taught by von Behring, the germs enter through the intestinal tract."

If this is so for the most common form of tubercular disease in man, other infective processes may yet be shown

to have their starting-point in the bowels; and it will become, as time elapses, increasingly important to take the utmost care to remove from our habitations and towns all those matters, like the excretal wastes of our bodies, in which infective organisms are so frequently found, and which can, after leaving the body of one person, so easily be introduced into the body of another by means of food and drink, where the proper means of removal of excreta are not at hand or are negligently used.

It must not be forgotten that the exact processes of infection in man are not yet fully understood. It is becoming more generally recognised that infection does not always follow upon the introduction into the body of the specific microbe, and that the latter may find a habitat in the body for a certain period without setting up disease. This is certainly true of enteric fever, of cholera, of diphtheria, and possibly of other diseases. Actual infection, it is conceivable, may depend upon *symbiosis*, that is to say, upon the conjoint action of what we regard as the specific microbe with some other organism or organisms, which, working in association, are enabled to overcome that natural resistance of the bodily cells or fluids, which is effective against the onslaught of the single species, but not against a combination of more than one enemy. The ally to the specific microbe may be a normal inhabitant of the mucous membranes or their secretions, or may be a chance visitant from without. If the former, its capacity for assuming virulence may be dependent upon some external cause, such as the breathing of foul air, the drinking of polluted water, the eating of tainted food, or the lowering of temperature by chill; and there are many disease-occurrences which are explicable only on the assumption that some disturbance of this kind was effective in im-

parting virulence to microbes already present in the mucous membranes.

The question of symbiosis in its relation to infection brings up again the problem of the part played by insanitary environment in disease causation. Just as in the past there was, perhaps, a disposition to overrate the importance of drainage defects and imperfect removal of excreta in the causation of disease, so at the present time there is a reaction in favour of considering the specific microbe as the be-all and end-all of infection ; and there is a tendency to disregard the other factors with which disease-occurrences are so often associated. It is becoming, however, more and more evident that infection is not always the simple process it is assumed to be, and that the infectivity of the specific microbe is liable to be conditioned by numerous other factors of which the *modus operandi* is but imperfectly understood.

STATISTICS

Table I.—England and Wales

Annual Death-rates per 1,000 *of Population in Groups of Years*

Period.	Death-rate.
1866–70	22·4
1871–75	22·0
1876–80	20·8
1881–85	19·4
1886–90	18·9
1891–95	18·7
1896–1900	17·7
1901–05	16·0
1906–07	15·2

TABLE II.—ENGLAND AND WALES

Annual Death-rates from Enteric Fever and from Diarrhœa per 1,000,000 of Population in Groups of Years

Period.	Enteric Fever.[1]	Diarrhœa.
1869–70	389	1088
1871–75	374	1031
1876–80	277	853
1881–85	216	672
1886–90	179	681
1891–95	174	652
1896–1900	175	819
1901–05	113	678
1906–07	79	586

TABLE III.—COUNTY OF LONDON

Notifications of Enteric Fever per Million of Population from 1890–1907

Year.	Rate per Million.
1890	688
1891	798
1892	577
1893	849
1894	772
1895	799
1896	722
1897	698
1898	676
1899	991
1900	951
1901	703
1902	744
1903	507
1904	408
1905	331
1906	339
1907	293

[1] Enteric fever was not separately recorded until the year 1869.

TABLE IV.—ENGLAND AND WALES

Annual Death-rates from Phthisis, from Septic Diseases, and from Puerperal Fever (Females) per Million of Population in Groups of Years

Period.	Phthisis.	Septic Diseases.	Puerperal Fever.
1871–75	2218	126	—
1876–80	2040	105	120
1881–85	1830	104	181
1886–90	1635	90	153
1891–95	1462	86	154
1896–1900	1323	75	120
1901–05	1215	80	106
1906–07	1145	80	87

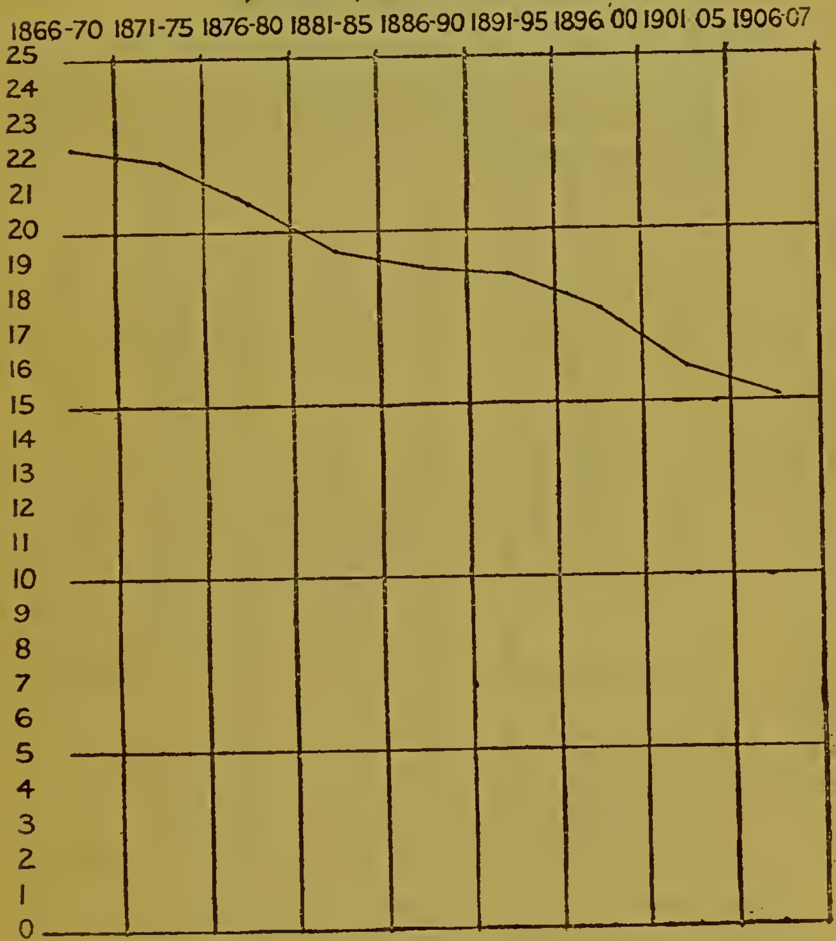
From these tables it appears that in England and Wales the *general death-rate* has been reduced 30·9 per cent. between the periods 1871–5 and 1906–7. The *enteric fever* death-rate for similar periods has been reduced to the great extent of 78·9 per cent. The *diarrhœa* death-rate has been reduced 43·2 per cent., and the *phthisis* (tubercular disease of the lungs) death-rate has been reduced 48·4 per cent.

The *general death-rate* has shown a fairly steady diminution each quinquennium, and so has the death-rate from *phthisis*. The *enteric fever* death-rate decreased rapidly in the first four quinquennia, but in the two following quinquennial periods (1891–5 and 1896–1900) the rate remained very nearly steady at the figure of the 1886–90 period. Since 1900 there has again set in a rapid decline. The *diarrhœal* death-rate has shown many fluctuations in the period under review, no doubt largely ascribable to variations in the summer temperatures of the different years; but many deaths of young children from diarrhœal

complaints were, and are still, attributed to *enteritis* and *gastro-enteritis*, and fail to be recorded under the *diarrhœa*

ENGLAND AND WALES

Annual Death-rates per 1000 *of Population in Groups of Years from All Causes*

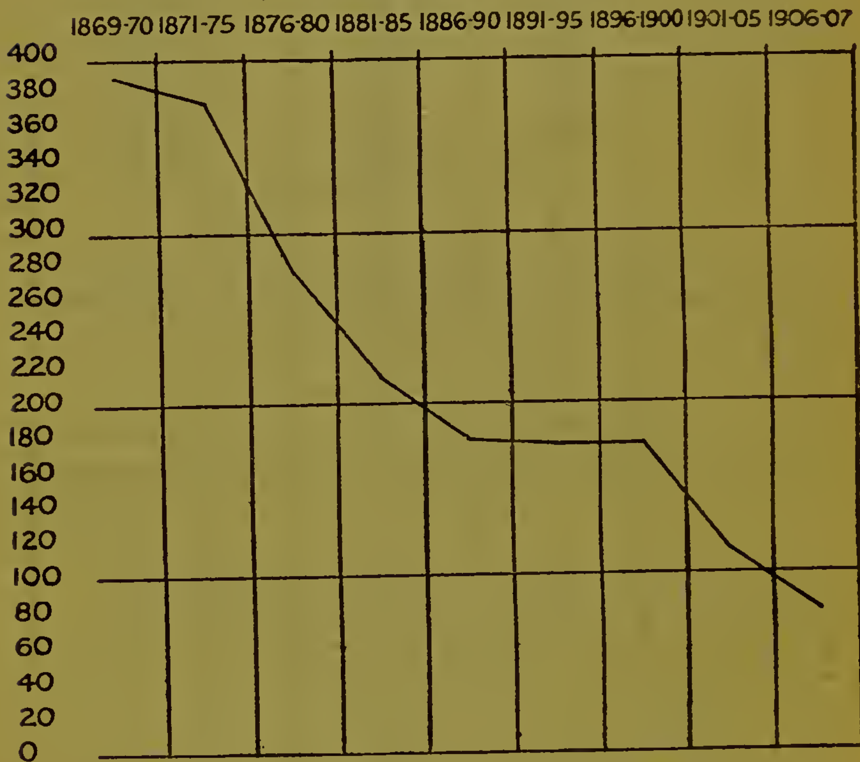


heading. There have also been considerable changes in the period under review, in the proportions of the deaths attributed to diarrhœa on the one hand, or to enteritis and its synonyms on the other; and it is difficult under

these circumstances to draw any very definite conclusions as to what the real diminution has been in the country as a whole of these diarrhœal affections, which have the major portion of their mortality in the third quarter of the year.

ENGLAND AND WALES

Annual Death-rates per Million of Population in Groups of Years from Enteric Fever

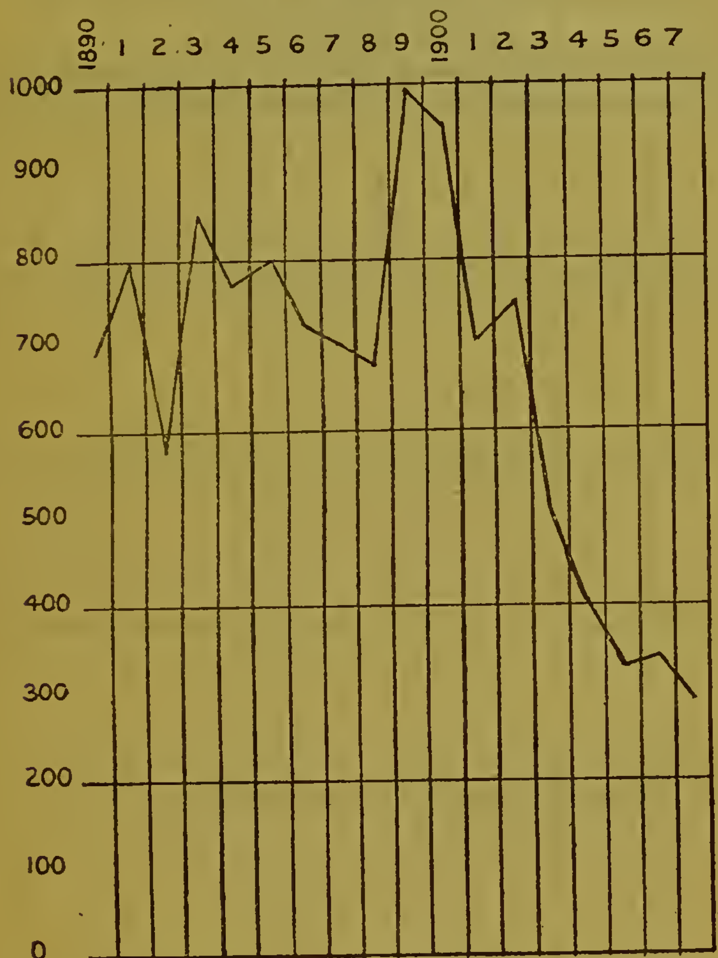


With regard to *enteric fever*, interesting speculations may be indulged in as to why the death-rate in the ten years 1891–1900 failed to show the diminution which had marked the previous twenty years, and as to why the downward progress of the disease has been so marked during the present century. In the absence of more

complete knowledge, these speculations are not perhaps very profitable ; but the recent resumption in the reduction

COUNTY OF LONDON

Notifications of Enteric Fever per Million of Population from 1890–1907

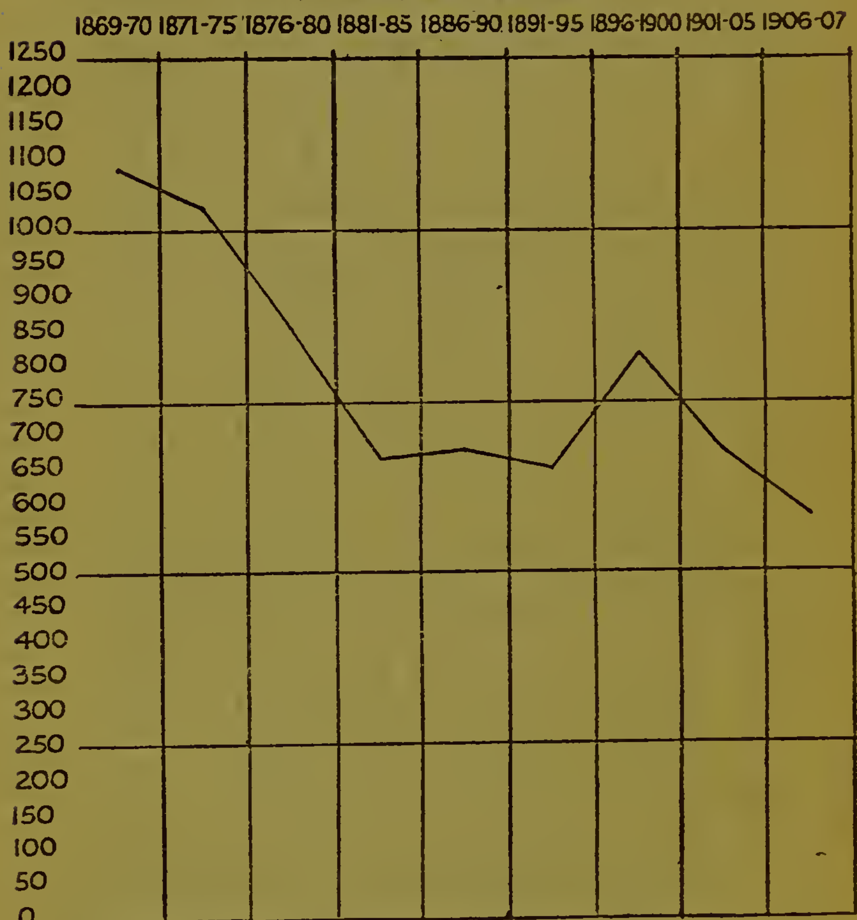


of enteric fever mortality may perhaps be attributed to a better understanding of the etiology of the disease in relation to (1) water supplies, (2) shell-fish, and (3) middens

and pail-closets, and to the improved methods of sanitary administration which have followed upon the recognition of the channels by which *enterica* is spread.

ENGLAND AND WALES

Annual Death-rates per Million of Population in Groups of Years from Diarrhœa

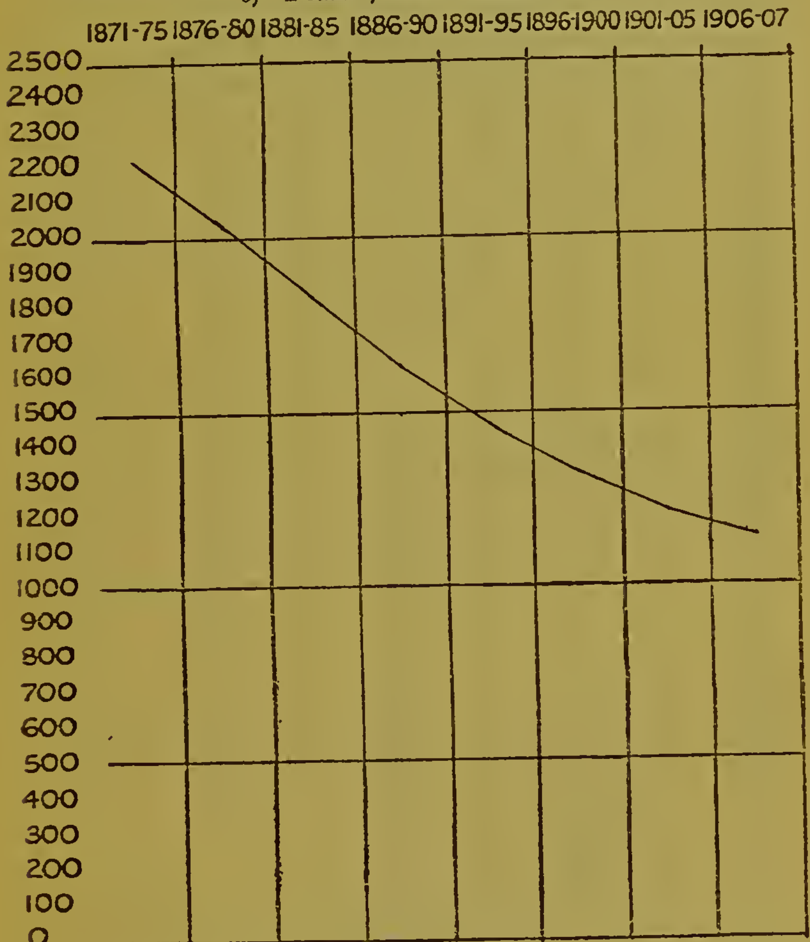


The remarkable reduction in the prevalence of enteric fever in the County of London since the year 1902 (see Table III. and Diagram) is probably in some considerable

measure due to the steps which have been taken of recent years to ensure that adequate storage and efficient filtration through sand of the Thames- and Lee-derived waters, which

ENGLAND AND WALES

Annual Death-rates per Million of Population in Groups of Years from Phthisis

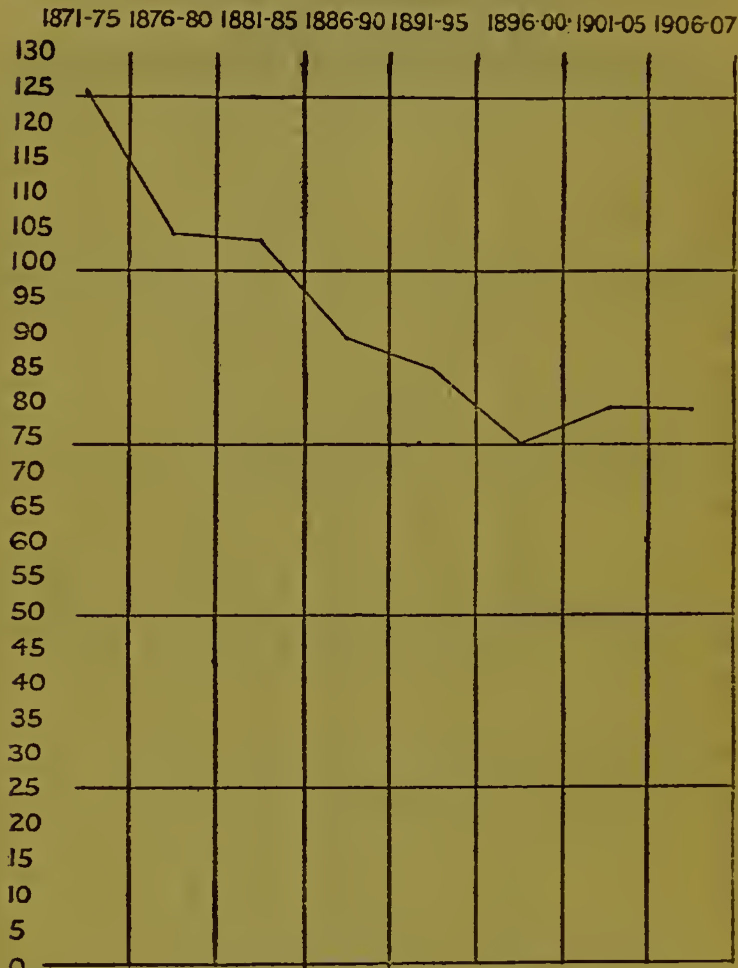


the progress of bacteriology has shown to be essential if river waters liable to sewage contamination are to be consumed with impunity by an urban population.

The appointment of a skilled bacteriologist (Dr. Houston) by the Metropolitan Water Board to the post of Director

ENGLAND AND WALES

Annual Death-rates per Million of Population in Groups of Years from Septic Diseases



of Water Examinations is probably not remotely connected with the existing comparative freedom of the population of London from water-borne enteric fever.

The reduction in the death-rate from *phthisis* has been a notable one, and characterised by exceeding steadiness from one five-year period to another; but little is known with certainty as to the causes of the diminution. There

ENGLAND AND WALES

Annual Death-rates per Million of the Female Population in Groups of Years from Puerperal Fever

are probably a variety of causes at work; but to improvements in domestic and municipal sanitation may fairly be ascribed some portion of the decline in phthisis mortality.

The *septic diseases*—by which is understood Erysipelas, Septicæmia, Pyæmia, Phlegmon, Phagedæna, and other

infective processes—show a decline in mortality from the period 1871–75 to 1906–07, namely, 36·5 per cent., but the decline was antecedent to twenty years ago, and since then the diminution has been quite inconsiderable. The decline in *puerperal fever* mortality has been in recent years considerably greater, namely, 42 per cent., if we take the average of the ten years 1876–1885 (150), and compare it with the average of 1906–7 (87).

There are, however, other reasons, such as the introduction of antiseptic methods into surgical and obstetrical practice, and modern improvements in nursing, which sufficiently explain any reductions in mortality from septic diseases and puerperal septicæmia during the past twenty or thirty years; and it does not seem possible to attribute any but a small part of the reductions in mortality, such as they are, to improvements in domestic hygiene or sanitary administration.

It is certainly interesting to note how little the mortality from septic diseases has declined during the past twenty years; but, possibly, the improvement is greater than the figures denote, as more accurate certification of the causes of death in recent years may have placed, under the heading of septic diseases, deaths which formerly would have been classified under diseases of special organs of the body.

CONSERVANCY METHODS OF EXCRETAL REMOVAL

It will be unnecessary to devote any extended consideration to the health aspects of these methods, as it has for long been recognised by sanitarians that they are inadequate to the requirements of our advancing civilisation, and are inseparably associated with dangers to the health of the communities resorting to them, that the water-carriage system of excretal removal is more nearly free from.

To those who are interested in the historical aspects of the question, a study of the Reports of the various Commissions appointed in early Victorian times to report upon the sanitary conditions then prevailing in this country, may be commended. The principal inquiries were those of the *Health of Towns Commission Reports*, 1844 and 1845; *General Report on the Sanitary Condition of the Labouring Population of Great Britain*, 1842, with a supplementary Report on *the Practice of Interments in Towns*, by Edwin Chadwick, 1843; *The Metropolitan Sanitary Commission*, first and second Reports, 1848; *The General Board of Health*, 1848–58; *The Sewage of Towns Commission*, 1857–65; and the *Rivers Pollution Commission*, 1868–74; whilst the Reports of the *Medical Officer of the Privy Council* (especially the ninth), 1866, the *Medical Officer of the Local Government Board*, and the *Sewage Committee of the British Association*, contain also much valuable information on this subject.

To those of the present generation who are familiar with the slum houses and courts of our great cities, and with the methods of excretal removal there prevailing under modern municipal administration—methods which are still in many instances imperfect, but which yet display some systematic control and care for the public health on the part of those who administer the Public Health Acts and municipal bylaws—the revelation of the deplorable conditions under which the poorer classes existed in many large centres of population in early Victorian times will no doubt come as a surprise. Thus, of one town we learn that in a great majority of the houses, even in the central parts, no "accommodation" of any kind was provided, and hence the adult male population defæcated habitually in the gardens or in the road. In another town, children's excrement and other refuse were frequently allowed to remain dotting the spaces around the houses. In certain colliery districts the roadways were a succession of dust-heaps used for all purposes of personal easement; and in another place, houses under £10 rental were not provided with privies or cesspools, the inhabitants using the open streets instead. Filth from the upper storeys of the houses was commonly discharged into the court or passage below. In those times it is stated that the whole of the cellar population of Liverpool, amounting to more than 20,000 persons, were absolutely without any place of deposit for their refuse matters, and a large proportion of the houses inhabited by the working classes in that city were in a similar predicament.

As some improvement on this loathsome state of things there gradually developed the setting aside of a special locality, where the refuse matter of one house, or often of many houses, could be deposited—in other words, a midden-

heap. To the midden-heap succeeded a midden-pit—a pit usually dug in the ground, and unlined with stone or brick, to serve as the receptacle for all the refuse and filth of the house.

A gradual awakening of the public conscience to the deficiencies of the midden-pit led to the inauguration of the privy and cesspool, which consisted of an excavation in the ground, usually of considerable size, lined with stone or brick, surmounted by a wooden erection, with a seat for the convenience of the users. As these lined pits tended to fill up—there being less percolation into the surrounding soil of the liquid contents than in the unlined excavations constituting the midden-pits—it was often thought necessary to provide an overflow for the escape of the liquid into the nearest drain, ditch, or stream.

Such primitive methods of storing excretal refuse, until such time as it is convenient to have it removed by the scavengers, are still in evidence in many rural and possibly even yet in some urban districts. For many years people were content to rely upon privies and cesspools, until in comparatively modern times the Local Government Board took the matter in hand, and by means of its Model By-laws gave an immense impetus to the adoption of improvements in these conservancy methods, which have borne fruit practically throughout the country. Put in a few words, the Local Government Board models for the construction of middens and privies—models which can be adopted by all the sanitary authorities of the country for their local bylaws—do away with the excavation into the ground, and require the receptacle for excreta to be above the ground-level, and to be merely the space under the seat, which must be lined with cement or other impervious material, and must not exceed a capacity of two cubic feet.

With middens constructed on these principles, lengthy storage is impossible, periodical removal of the contents about once a week is imperative, and the dangers of soakage of the liquid contents into the soil around are reduced to a minimum. If the midden-contents are covered daily with dry ashes and cinders, some of the liquid is absorbed, and the mass is rendered drier, with a consequent lessened tendency to putrefaction and the escape of foul gases. There is still, however, the disturbance of the refuse when dug out by the scavengers, and placed in buckets or pails for removal (often through the house) to the scavengers' carts; and to obviate the nuisance so caused, which is very frequently the subject of complaint, and often leads to undesirable postponements of the scavengers' calls, it was by many considered that all the excretal refuse should be collected in a pail constructed of stout tarred oak or of galvanised iron, to be placed under the seat on the concreted floor of the privy. The pail should be provided with an air-tight cover, to be adjusted before its removal to the scavengers' cart.

We seem to have arrived, with this device, at the *ne plus ultra* of conservancy methods of treatment—a strong water-tight pail constructed of impervious material, of small capacity, and provided with an air-tight cover; small enough to be easily conveyed to the cart, and so to the municipal depôt, where it is emptied and cleansed, and large enough for the weekly requirements of an ordinary household. If, in addition, the pail-contents are kept dry with cinders and ashes, as they easily may be in urban districts, or with dried and sifted earth of suitable quality in rural parts, it is difficult to see how the pail system as a conservancy system can be improved upon.

It is unnecessary to dilate at any length upon the sanitary

dangers of the older systems which the improved above-ground middens and pails have superseded. The old-fashioned privies and middens and cesspools gave rise to a constant poisoning of the air in their vicinity; there was also an ever-present liability to overflow and fouling of the ground surface around them, and of danger to water-supplies from percolation of the liquid filth into the subsoil water. In the days now gone by, which are so intimately depicted in the reports of the *Health of Towns Commission*, not only must these places have been unapproachable by cleanly and decent people, but the stinted accommodation, such as it was, almost everywhere available for the poorer class of tenant, must have largely determined the practice of indiscriminate deposition of dejecta in the courtyards, gardens, and roadways of which the Commissions give an account. Under these conditions, the poor of our great centres of population were exposed to every possibility of infection described in the first of these Chadwick lectures. There was the danger of infection by direct contact—the people brought fæcal matter with them into their houses on their hands, feet, and clothing from the middens and the ordure deposited around. There must have been infection by flies, by dust, by foul gases when the midden-contents were stirred up, and by pollution of the water of the wells from which they drank. No wonder that the haunts of the poor were fever-stricken, and that the mortality was terrible. Not only this, but the absence of any possibility of decency and cleanliness engendered rough habits and a low standard of life; and a moral code in keeping with their surroundings was the necessary consequence of life under these conditions.

All this has very much altered for the better. The old-fashioned systems are being, or have been discarded, and

the improved middens or pails on the Local Government Board model have either taken their place, or the conservancy system has been entirely abandoned in favour of the water-carriage system. So far, so good; and we are all agreed that the old-fashioned methods of the past must go, as being quite irreconcilable with modern conceptions of health and decency.

The question, however, now arises whether in urban districts it is a sound policy to retain any conservancy method, even the best, and whether the time has not come for the steady, if gradual, replacement of such methods by the water-carriage system of excrement removal. In regard to rural districts the position is slightly different, and the question here must be considered separately.

The advantages claimed for the pail system being retained or developed in urban districts, to replace the older conservancy methods, may be briefly stated as follows: (1) That less water is required for use in the houses, and that, the solid excretal filth being kept out of the sewage, the latter is weaker in character and more easily subjected to purification than where water-closets are in use. (2) That the people for whose use the pails are supplied are of a rough class, and would not know how to use the delicate apparatus of the water-closet, or would, from their destructive habits, do so much damage as to render the water-closet system impracticable.

With regard to (1), it is no doubt the fact that less water is required per head of the population where a pail system is in use than where a water-closet system has been adopted; and this may be a consideration of importance in places where the available water-supply is of a limited character. On the other hand, if it is really of importance to the health of the community that water-closets should be substituted

for pails, no considerations of economy should be allowed to stand in the way of so increasing the sources of water-supply as to provide what is necessary in the interest of public health. It must also be remembered that it is not usual for municipal authorities to impose restrictions as to the use of water-closets in the better class of houses of a town; and it is certainly undesirable that the benefits of improved sanitation should be capable of application to only one class of the community, and that not the class which is most in need of sanitary advancement.

Neither is the nature of the sewage very materially altered when water-closets are substituted for pails. In towns relying largely upon the pail system there must be drains from the houses and sewers in the streets to remove the house waste-waters and slops, which include a considerable proportion of the daily urine evacuations of the population. Sewage consequently is produced which is of a highly polluting character, and quite unfit to be discharged in a crude condition into streams and water-courses.

The First Report of the *Rivers Pollution Commission* is quite definite on this head. It is there stated that there is a remarkable similarity of composition between the sewage of midden towns and that of water-closeted towns. The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter; whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage. For agricultural purposes ten tons of average water-closet sewage may, in round numbers, be taken to be equal to twelve tons of average privy sewage. The Committee of the Local Government Board on *Modes of Treating Town Sewage* also reported that the entire excreta of a town population added to the waste water of the population is, by volume, only about

as 1 to 100; consequently there is no necessity to enlarge the capacity of sewers originally intended only for the conveyance of waste waters, when it is decided that such sewers shall receive the entire excretal refuse of the population.

It will, therefore, be seen that any question of increased cost of sewers or of their maintenance, or of disposing of the sewage of a town after the conversion of pails into water-closets, is not one of any unsurmountable difficulty, and should not be allowed to override weighty considerations of public health.

The objections to the pail system are (1) that it is contrary to the principles of hygiene to allow excretal matters to be retained in, or within, the immediate vicinity of habitations, and that such retention is injurious to health, even when the administration is good, the periodical removals being undertaken regularly and at short intervals. The second objection is that the pail system is not so conducive to education in cleanliness and sense of decency as are water-closets in the houses of the working classes. With the young especially it is eminently desirable that habits and standards of decency and cleanliness should be formed in youth; and it is now sufficiently recognised how difficult it is to inculcate such matters as educational precepts, if the homes of the children are the very antithesis of what they learn at school.

The argument that water-closets are unsuited to the needs of rough and careless tenants should not be allowed to weigh unduly against considerations such as the above. In many large cities, such as London, water-closets are universally supplied; and, on the whole, the results are exceedingly satisfactory, if the social position of many of the users be kept in mind. It is, of course, necessary to supply

a strong and simple kind of closet, and one not easily put out of order; but there are many such on the market at the present time. In any case, it is a national duty to educate and train our less-refined citizens in habits of cleanliness and decency, as well as to safeguard their health; and, if these two great national objects can be promoted by the introduction of the water-carriage system of excretal removal, wherever it is properly applicable, then sanitary authorities have a clear duty before them in the interests of our national efficiency.

On the health aspects of the improved midden and pail systems, as contrasted with water-closets, no better or more conclusive evidence can be obtained than that which has been so ably prepared by Dr. Boobbyer, Medical Officer of Health of Nottingham, during the past eleven years, in respect of the enteric fever incidence on the populations in the houses using the different systems.

City of Nottingham

Incidence of Enteric Fever Cases upon Houses with Pail-closets, Midden-privies, and Water-closets, from 1887 *to* 1907, *and upon Waste-Water-closets during* 1905-07

1887 to 1898 (Average)

Houses with pail-closets ..	1 case of enteric fever in 120 houses.
,, ,, midden-privies ..	1 case of enteric fever in 37 houses
,, ,, water-closets ..	1 case of enteric fever in 558 houses.

1899

Houses with pail-closets	1 case in 70
,, ,, midden-privies	1 ,, 18
,, ,, water-closets	1 ,, 296

1900

Houses with pail-closets	1 case in 92
,, ,, midden-privies	1 ,, 20
,, ,, water-closets	1 ,, 407

1901

Houses with pail-closets	..	..	.. 1 case in 84
,, ,, midden-privies	..	..	.. 1 ,, 12
,, ,, water-closets	..	..	.. 1 ,, 255

1902

Houses with pail-closets	..	..	.. 1 case in 129
,, ,, midden-privies	..	..	.. 1 ,, 21
,, ,, water-closets	..	..	.. 1 ,, 294

1903

Houses with pail-closets	..	..	.. 1 case in 267
,, ,, midden-privies	..	..	.. 1 ,, 50
,, water-closets	..	..	.. 1 ,, 504

1904

Houses with pail-closets	..	..	.. 1 case in 166
,, ,, midden-privies	..	..	.. 1 ,, 50
,, ,, water-closets	..	..	.. 1 ,, 407

1905

37,048	houses with pail-closets ..	204 cases	.. 1 case in 181
400	,, ,, midden-privies	4 ,,	.. 1 ,, 100
12,000	,, ,, water-closets..	21 ,,	.. 1 ,, 571
6,785	,, ,, waste-w.c.'s..	26 ,,	.. 1 ,, 261

1906

36,886	houses with pail-closets ..	231 cases	.. 1 case in 160
300	,, ,, midden-privies	3 ,,	.. 1 ,, 100
14,000	,, ,, water-closets	21 ,,	.. 1 ,, 667
6,785	,, ,, waste-w.c.'s ..	30 ,,	.. 1 ,, 226

1907

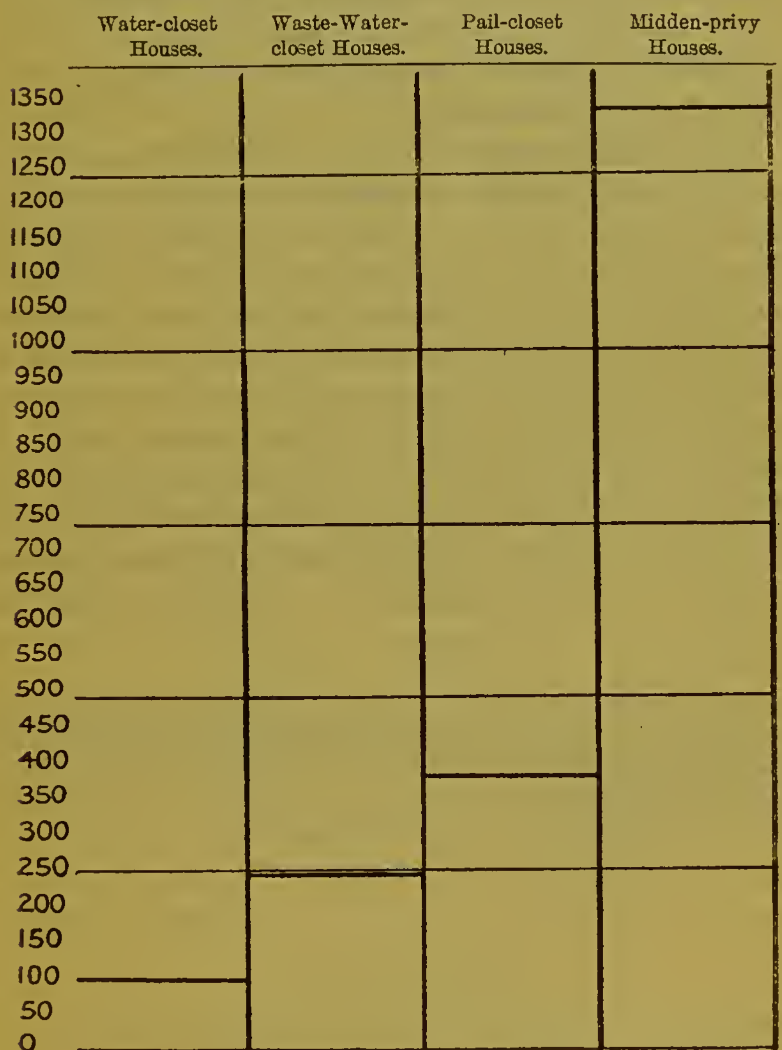
36,697	houses with pail-closets ..	177 cases	.. 1 case in 207
200	,, ,, midden-privies	11 ,,	.. 1 ,, 18
18,395	,, ,, water-closets	25 ,,	.. 1 ,, 736
6,785	,, ,, waste-w.c.'s ..	18 ,,	.. 1 ,, 377

Summarising this table for the three years 1905, 6, 7, we find that there was :

1 case of enteric fever in	673	houses with Water-closets
,, ,, ,,	271	,, Waste-water-closets
,, ,, ,,	181	,, Pail-closets
,, ,, ,,	50	,, Midden-privies

CITY OF NOTTINGHAM

Average Incidence of Enteric Fever Cases during the three years 1905, 6, 7, *upon Houses with Water-closets, with Waste-Water-closets, with Pail-closets, with Midden-privies. Incidence on Water-closet Houses taken as* 100



Or if we take the incidence of enteric fever on water-closet houses as 100, the incidence on waste-water-closet houses was 248, on pail-closet houses 372, and on midden-privy houses, 1,346.

The enormous advantage of pail-closets over midden-privies is obvious from these figures, but at the same time it will be observed that the incidence of enteric fever on the pail-closet houses is more than 3½ times that recorded for the water-closet houses.[1]

For country cottages or houses an earth-closet or dry-ash pail-closet, outside the house, is very often an indispensable adjunct. It is a matter of general agreement amongst sanitarians that these types of closet should not be placed within the structure of the house. However capable the control, there is always a certain amount of effluvium arising from the deposited excreta, and the closet forms an attraction for flies. Where garden ground is available, the pail contents or earth compost can be dug into the soil ; and, on the whole, there is less difficulty in disposing of the house waste-waters by irrigation or sub-irrigation of adjoining ground if the solid excrement is kept out of the house sewage.

[1] In Nottingham, difficulty has been encountered in the replacement of middens and pail-closets by water-closets, as the existing supply of water to the city is inadequate, and cannot readily be extended.

MODERN METHODS OF HOUSE DRAINAGE AND SEWERAGE

THE successful results of the working of the water-carriage system of removal of excreta, as contrasted with those of any of the conservancy systems, are due to the fact that by this system all excretal matters are expeditiously conveyed away from the houses and towns by water flowing down suitably inclined pipes, drains, and sewers. There are other methods of sewerage, such as the Liernur system, in which the excreta mixed with water flow into hermetically sealed pipe sewers, which are partially exhausted of air, and the sewage is in consequence drawn by suction to a depôt outside the town. Such methods are in use in Holland, where the country is very flat, and the subsoil is water-logged, so that gradients for self-cleansing drains and sewers are difficult to obtain, but are not required, as a rule, in this country.

It will be unnecessary to consider in any detail the arrangements appropriate for a water-carriage system of house drainage and sewerage, which are now well known and perfectly understood; but it will be desirable to consider briefly as to any defects or shortcomings in our modern systems of sanitation, more especially in their relation to health.

WATER-CLOSETS

The best types of modern water-closet are admirably adapted for the purposes they have to serve, and it is

difficult to see that much, if any, improvement is possible. The Wash-down Pedestal Closet, the Siphonic Closet, and the Valve Closet are all alike good for the following reasons: (1) the excreta are received directly into water in the pan or basin; (2) there is little or no soiling of the sides of the basin above the water-line; and, (3) the flushing water conveys the excreta away to the drain or soil-pipe, and leaves the basin and trap charged with clean water. Consequently there is no deposit of excrement on any part of the apparatus above the water line, and the dangers arising from foul odours, dust, and flies are entirely obviated. The internal surfaces of the soil-pipe and connected drains beyond the trap of the water-closet must necessarily be fouled; but any gases or vapours arising from decomposition of deposited matters in these positions are prevented from passing back into the house by the water seal of the water-closet trap; and modern methods of trapping and ventilation ensure that any gases formed in soil-pipes and drains escape through a terminal ventilator outside the house on the roof level and clear of windows and chimneys.

Water-closets, slop-sinks, urinals, gulley-traps, and drains are now constructed of smooth, glazed, nonporous, impermeable ware (fireclay, china, or stoneware), which is resistant alike to the chemical action of drainage gases or liquids, and to mechanical erosion by grit or hard bodies in the sewage. The smooth surfaces are highly unfavourable to the deposition of solid filth from the sewage.

The amount of water necessary for effectual flushing varies with the different types of water-closet. For closets of the Pedestal Wash-down type the minimum amount of flushing water should be two gallons, and three gallons is often preferable. The experiments made by the

Royal Sanitary Institute in 1893 very clearly indicate that two gallons is the minimum allowable, if the water-closets and connected drains are to be maintained in a self-cleansing condition.

Colonel Ducat, R.E., who, in 1895, conducted a Local Government Board inquiry under Section 19 of the Metropolis Water Act, 1871, as to the maximum flush of water permissible for water-closets, reported that the necessity was not proved for increasing the maximum flush permissible from two gallons to three gallons.

The water-closet apparatus of Pedestal type should be unenclosed in woodwork, and the seat should be hinged for lifting, so that the floor and wall angles below the seat-level can be readily inspected and cleansed. For closets used entirely by males, a strip of hard wood attached to each side of the upper rim of the water-closet basin is, perhaps, even preferable to a lifting seat if the water-closet is not used for urinal purposes, as the front inner edge of the seat may become soiled by urethral discharges. For closets used by women the ordinary lifting seat is preferable.

In public water-closets, such as those maintained by Railway Companies and Municipalities, the French system of providing for each user a paper pattern cut to the shape of the water-closet seat, on which the user can rest the thighs and buttocks, might well be adopted in this country as a safeguard against the contamination of the person or clothes by infective discharges.

For most Valve closets a wooden riser and top enclosure are necessary to conceal and protect the mechanisms connected with the lifting handle for opening the clack-valve and for the water supply to the basin. Wherever these closets are used for the reception of slops, or as urinals, the basins should be provided with slop-tops, to which the

surrounding woodwork should be accurately fitted, so as to prevent escape of foul liquids into the space beneath the seat, where they escape observation and give rise to foul odours. A leaden safe-tray is usually fixed on the floor beneath a Valve water-closet to collect any overflow from the basin and convey it through a short length of waste-pipe to the open air. These safe-waste-pipes should always be provided at their open ends with a brass flapper to prevent cold currents of air passing into the space under the water-closet seat, such cold draughts of air being often causative of sciatica and rheumatism in people predisposed to these affections.

An objection has been raised to the water-closet now in use that the top edge of the basin is too high above the floor, so that what has been described as the "natural attitude" cannot be assumed during the process of defæcation. The natural attitude is said to be the crouching position that is involuntarily assumed by any person in defæcation who has nothing to sit upon. In this position the thighs are completely flexed, so that they are in apposition with the front walls of the abdomen, and there is in consequence a certain pressure exerted by the extensor surfaces of the thighs upon the external inguinal rings. It is said that in this attitude the straining effort is powerless to produce a hernia or rupture. It seems very doubtful, however, if hernia has ever been produced in a person with normal inguinal canals by straining at stool, as the contraction of the abdominal muscles under these circumstances cannot be anything like so powerful, as when the body is stooped in the attitude necessary for lifting a weight with the hands and the upper part of the trunk is fixed. In any case, a very low water-closet basin is uncomfortable for old people, who have a difficulty in rising from such a low attitude,

and does not seem otherwise necessary. It is, probably, better to combat constipation and straining by diet, exercise, and suitable aperients or enemata, than by the assumption of particular bodily postures in the water-closet.

Although, unlike earth- or pail-closets, water-closets may be placed within buildings, it is best that they should be placed in a compartment with one external wall, so as to obtain light and ventilation direct from the outer air, and they should also be isolated from the rest of the house by an intercepting lobby—cross-ventilated if possible. Even with the best modern water-closet apparatus, although the excreta are rendered practically inodorous as soon as they are covered with water, a certain amount of smell is necessarily engendered by the person using the closet, and it is for this reason undesirable that the air of the closet should gain access to the house.

Waste-water-closets and Latrine-trough-closets

Waste-water-closets are, no doubt, superior in many respects to the pail-closets of the conservancy system, but they are, as sanitary appliances, inferior to modern water-closets of the ordinary type. From Dr. Boobbyer's statistical returns for the city of Nottingham, it will be seen that the enteric fever prevalence in houses supplied with waste-water-closets was, on an average for the three years 1905–6–7, two and a half times as great as in the houses where water-closets of the usual type have been fitted.

It is evident, then, that these closets do not so satisfactorily meet the requirements of a proper system of excretal removal as do the ordinary types of water-closet. The reason probably is that, owing to the necessities of

construction, there is a considerable surface of apparatus exposed to fæcal contamination which is never flushed with water. The old nuisances inseparable from the privy and midden are repeated in a minor form in the waste-water-closet. Fæcal deposits are left exposed to the air; and the dangers arising from foul gases, dust, and flies, are not overcome to anything like the same extent as they are where good modern water-closets are in use.

Owing also to the only water which is used for flushing these closets being the waste waters from the household sinks, the house drains are imperfectly cleansed; and the sewage leaving a district containing many houses with waste-water-closets is so exceptionally foul and strong, that great difficulty is experienced in purifying it without nuisance when it arrives at the sewage works.

In consequence of these defects, waste-water-closets are no longer regarded with favour by medical officers of health; and in the Midlands, where fairly extensive trials of the system have been made, the tendency is to revert to the ordinary type of water-closet as a substitute for middens and pail-closets.

The *trough water-closet*, especially the modern form with isolated basins and automatic flush, is less open to objection on public-health grounds, as, if there is any retention of excretal matter in this form of latrine, it is after the excreta have been deposited in water. The liability to nuisance and danger is for this reason very much less than where excreta are exposed, and become dry in the air. Latrines of this kind have been largely adopted for institutional use, for elementary schools, and for barracks; but it is now very generally held that it is better to educate children, soldiers, and the inmates generally of institutions, in the right usage of ordinary water-closets,

and that appliances which leave so little to the initiative of the user are undesirable, as fostering habits of indifference and carelessness, and failing to inculcate any lessons in self-respect and decency. It is for these reasons that the use of separate water-closets is being so largely extended in our elementary schools and in the barracks of the United Kingdom. The individual user should be held responsible for the cleansing and flushing of the apparatus.

Soil-pipes

Lead and iron are the best materials for soil-pipes, lead being preferable, as affording the smoother surface. The modern principles of soil-pipe construction seem to be perfectly sound; and the anti-siphonage pipes to prevent siphonage of the water-closet traps, as now so universally applied, are undoubtedly a necessary adjunct, both for this purpose and to provide ventilation for branch soil-pipes which would otherwise be unventilated. Soil-pipes fixed outside the walls of houses are generally advocated now, and there is undoubtedly some risk from the use of internal soil-pipes. Where soil-pipes are, from one reason or another, carried inside a building, they should be protected from injury by a sheathing of plate iron on the surface exposed, behind a wooden casing or in a chace in the wall. Nails are frequently unwittingly driven into lead pipes behind skirtings and casings. The necessity for water- and air-tight joints to all soil-pipes and their branches, and to soil-vent-pipes, need not now be insisted upon.

House-drains

As for soil-pipes, the principles concerned in the construction of house-drains hardly nowadays admit of

discussion. The only points on which some difference of opinion may be allowed are as to whether iron drains or stoneware drains are the best, and as to the necessity for the disconnecting trap which severs the aerial connection between the house-drain and the cesspool or sewer.

Stoneware of good material and highly glazed is not subject to corrosion like iron, but the pipes are necessarily brittle and easily crushed or fractured by heavy weights, ground settlement, or the vibration of the earth produced by heavy wheeled traffic. The *iron* pipes now used in drainage, with caulked lead joints, will withstand pretty nearly any strain they are likely to be subjected to; and this is a matter of very considerable importance for houses adjoining streets or highways, where the recent developments of heavy motor traffic cause such serious ground jarring and vibration. On the other hand, even although the pipes are barffed (coated inside and out with the magnetic oxide of iron) or covered with Angus Smith's protective tar solution, they do in the course of time corrode. A corroded iron pipe presents a rough, fretted surface, in which sedimentary matter lodges; the flow of sewage along the pipe is in consequence delayed, and in time, of course, the pipes may become quite eaten through with rust. What the length of life of iron drainage is, under the varying circumstances in which it is used, is still unknown. Of recent years glass-glazed or vitreous enamelled iron pipes have been used for drainage work; and it is said that this glaze or enamel is imperishable, and does not crack or become dissociated from the metal by blows or rust. Such glazed pipes are, however, much more costly.

The *disconnecting trap* on the house-drain undoubtedly acts to a certain extent as an impediment to the flow of

sewage, and hinders that immediate escape of all sewage matter from the precincts of the house that is so desirable in theory. On the other hand, it prevents the passage of sewer-air along the house-drain or soil-pipes to escape at places where possibly a large outflow of sewer-gases would be eminently undesirable. For, in sewer ventilation, it must be recollected that the inflow and outflow of air from the sewers are very variable, depending as they do on wind, air temperature, barometric pressure, volume of sewage in the sewers, and many other indeterminate factors, and that the ventilation of sewers is practically incapable of being controlled or regulated. Consequently, at certain parts of a district in which the house-drains are directly connected to the sewers, large volumes of sewer-air may be almost continually escaping through a very few house-drains and soil-pipes, whilst in others there may be complete stagnation, or the house-drains may be acting as air intakes. As previously pointed out, Horrocks's researches at Gibraltar show that sewer-air may at times be specifically infected; and it is dangerous to permit such infected air to pass through drains and pipes actually within or close to houses, as the security of all drains and soil-pipes against leakage cannot be absolutely guaranteed.

Moreover, the disconnecting trap has two positive advantages of its own, in that (1) it permits each house-drainage system to be ventilated separately with its own fresh-air inlet and foul-air exhaust, thus providing that comparatively fresh and pure air is continually circulating throughout the house-drains and soil-pipes, and (2) it prevents the access of rats from the sewers into the house drains.

The investigations of Plague Research Committees in

India and elsewhere have shown the immense part played by the rat in the propagation of plague epidemics, and how important it is in places liable to be attacked by plague for rats to be kept away from inhabited houses. Rats which have gained access to the interiors of drains are very destructive in their search for food, and can gnaw their way or force a passage through weak places, and so obtain entrance to the house.

The exclusion of rats and sewer-air from the interiors of house-drains, and the provision of separate ventilation for the house-drainage system, are advantages conferred by the disconnecting trap which distinctly outweigh its acting in some degree as an impediment to the flow of sewage away from the house.

It is true that a disconnecting trap may occasionally become choked with a cloth or brush improperly introduced into the drain, which then becomes obstructed. This, however, is really more an argument for proper periodical inspection of all house-drainage systems than a reason for discarding the principle of disconnection.

If, as there is now reason to believe, from the researches of Horrocks and Andrewes, the air of sewers may contain at times the causal agents of enteric fever and other diseases spread by bacilli of intestinal type, the obvious use of the disconnecting trap in preventing the passage of such air into house-drains needs no insisting upon, for Horrocks did in fact conclusively show that the disconnecting trap effectually fulfils this purpose.

As regards the position of the air-inlet in relation to the house-drainage system, this should, of course, be as far removed from the house as circumstances will permit, as a back flow of air from the drains is at times unavoidable. From Horrocks's work at Gibraltar, it would appear prefer-

able to have the air-inlet raised some distance above the surface of the ground, rather than to have a ventilating grating at ground level or but slightly raised above the ground; for when the air-inlet acts as an outlet, as occasionally happens, there is a liability to the escape of sewage bacteria with the air when the inlet is situated at or about the ground level. When the inlet is carried by a pipe well above the ground, the liability to the escape of sewage bacteria would appear to be considerably less.

Treatment of Waste-pipes

The proper treatment of waste-pipes of sinks, baths, and lavatory basins has not yet been established on a firm basis. There is an impression prevailing that if waste-pipes do not receive urine or solid excreta, there is no particular danger from the gases and emanations that are given off from the interiors of such pipes. This impression is, however, an erroneous one, as in my own experience, and no doubt in that also of many other sanitarians, the escape of foul air from the waste-pipes of baths and sinks has been the cause of a considerable amount of ill-health.

The illness has usually taken the form of sore throat of septic character, and in certain instances true attacks of diphtheria have apparently been determined by the breathing of foul air from waste-pipes. This is not to be wondered at when we realise that secretions from the mouth, nose, and throat, and waste matters from the skin, are contained in the discharged waters from baths, sinks, and lavatory basins, as well as decomposable matters like soap, fat, and organic débris from the surface of the body. These matters adhere to the internal surfaces of the waste-pipes, or to the hopper-heads on the rain-water or down pipes (into which

waste-pipes from the interior of the house are often made to discharge), with the result that if the waste-pipes are untrapped, or the traps are sucked as the result of siphonage, or the hopper-heads are near windows, foul air, very possibly conveying particulate matter from the partially dried deposit, finds its way into bedrooms, or into bath-rooms adjoining the sleeping apartments, and is inhaled by the occupants of these rooms.

It is not necessary to presuppose the existence of specific septic organisms in the foul air from the waste-pipes, although, from what has been already said, it will be readily conceivable that such may occasionally be present; but the organisms that cause septic infection may be present as occasional or chance visitants in the throats of healthy persons, and the breathing of foul air or the introduction with such air of other microbes which favour symbiotic action, may prove the stimulus necessary to the initiation of virulence in the organisms present in the throat, which in the absence of such stimulation might have continued to be without harmful influence on their host.

From the foregoing it will be gathered that as a matter of precautionary routine it is desirable that all waste-pipes should be S-trapped under the apparatus—bath, sink, or lavatory basin; that where there is a liability to siphonage, the trap should be ventilated to prevent siphonic action; and that hopper-heads should only be used to receive waste waters where the head can be placed on a blank wall away from windows.

The usual method of ventilating the trap of a bath, sink, or lavatory basin, is to carry the vent-pipe through the external wall to terminate flush with the outer surface of the wall. Occasionally this is all that is requisite; but in cases where several waste-pipes join one main waste-pipe,

there would be danger by this method of the escape of foul air near windows. In such instances the anti-siphonage pipes from the traps should be united from below upwards and carried up to the roof for ventilation, or be branched into the ventilator of the main waste-pipe, in exactly the same manner as the anti-siphonage pipes of water-closets are connected with the soil-pipe ventilator.

These precautions in the fixing of waste-pipes are especially necessary in the lofty blocks of mansions and flats which are now so largely replacing in our large towns the older type of dwelling designed for one family only. In these mansions there are a great variety of fittings on each floor, and the discharge of upstairs kitchen or scullery sink water, and bath or lavatory water into a series of open hopper-heads outside the house, but close to windows, is quite indefensible in the light of accumulated experience. It is certainly preferable that all waste-pipes and their ventilating pipes should be closed pipes, opening below over the disconnecting gulley in the basement and terminating above with open ends on the roof away from windows. The joints of these pipes should be as securely made as the joints of the pipes conveying excretal matters from the bowels and kidneys.

SEWERAGE

All public sewers, like all private house-drains, should be water-tight conduits, and this is now the invariable desideratum sought by sewerage engineers. That it is always attained in practice is not perhaps so certain. Sewers as originally constructed in this country were not water-tight; they admitted subsoil water, and consequently acted as land drains. But at the same time they often

permitted sewage to escape into the subsoil, with all the dangers of contamination of water-pipes, water-mains, and shallow wells pertaining to such escapes, which a proper system of sewerage is intended to obviate.

That it is very often desirable to drain a water-logged subsoil all will agree, but the proper method of effecting this object is to install a system of subsoil drainage absolutely distinct and separate from the sewers that convey the sewage and waste waters away from the houses and town.

The effects of subsoil drainage upon the health of a community are somewhat outside the scope of these lectures; but there is a general agreement that health is promoted by measures which prevent rapid or extensive variations in the level of the subsoil water of inhabited sites, and which secure dry foundations and dry basements for the houses of the district.

Separate or Combined Systems of Sewerage

Theoretically, the advantage is on the side of the separate system of sewerage, which intercepts rain and surface water from the soil-drains and sewers of the district, and provides a separate system of pipes and conduits for the conveyance of such surface water to an outlet into a stream or river or other natural drainage channel for the locality.

Where sewers are designed only for house sewage and waste waters, and for manufacturing wastes, they may usually be of much smaller dimensions than where provision must also be made for the rainfall. Small sewers may be formed of stoneware or iron pipes—which are more impermeable, cheaper, and more easily laid than the brick sewers usually requisite for the combined system of sewer-

age. Pipe sewers are more easily flushed and cleansed, are less liable to sedimentary deposit, and convey the sewage away more rapidly than brick sewers, and, in consequence, are more in accordance with the principles of hygiene than are the latter. There is a less generation of sewer-gases, and there is a much smaller reservoir for air in the pipe sewer above the ordinary water level of the flowing sewage. The ventilating exchanges in the pipe sewer are also more complete and rapid than in the brick sewer, and in consequence there is much less liability of nuisance arising from the sewer-air accumulations that are so often the cause of annoyance and injury with brick sewers.

The pipe sewers on the separate system are necessarily deprived of the flushing effects associated with rainfall, but this disadvantage can be met by the installation of automatic siphon flush-tanks to discharge into dead ends at the heads of the branch or tributary sewers—a system of flushing which is certain in its action and capable of control and regulation. This is more than can be said of any flushing due to rainfall, which often is absent during the summer months, when sewer deposits are most frequent and most offensive.

If the sewage has to be purified before discharge, the exclusion of rain-water from the sewers is an enormous advantage, as the Local Government Board regulations require similar treatment for sewage diluted to three times the dry-weather flow, to that which is requisite for the ordinary dry-weather flow. The difficulties of dealing at sewage works with large quantities of dilute sewage are very much the same whatever be the method employed in the purification.

On the other hand, there are many practical difficulties in the way of the separate system with its two separate

sets of conduits—one for sewage and the other for storm waters. It is also, to say the least, doubtful whether it is a sound policy in the hygienic sense to treat the surface washings from the yards and enclosed areas around houses, and from public streets and carriage-ways, as if they consisted of unadulterated rain-water, and required no kind of treatment before discharge into a stream. Such surface washings are often polluted with human excretal matters, and contain the excretal refuse of such animals as horses, oxen, dogs, fowls, pigeons, and other domesticated creatures. The rain-water from the roofs of houses can, no doubt, generally be conveyed without offence direct to a stream; but as soon as the rain reaches the ground level in the neighbourhood of houses, it can no longer be regarded as uncontaminated. The polluting ingredients it then receives may be such as to cause danger to the public health in the event of the stream into which the rain-water drains discharge being used for potable purposes below the point of discharge.

On these and other grounds, then, it is only perhaps under exceptional circumstances that the separate system of sewerage can be advantageously adopted for urban communities; although for isolated mansions or institutions, where the details of the scheme can be properly worked out, the exclusion of rain-water from the soil-drains generally offers very great advantages.

From one point of view—that of subsequent purification of the sewage—a system of pipe sewers is in some respects less conducive to treatment at the outfall than a system of brick sewers. With pipe sewers in small towns the sewage arrives in a fresh condition at the sewage works, with the solids but little broken up and interspersed with the liquid. With brick sewers, however, owing to the

longer time taken to reach the outfall, and the much larger capacity of the sewers, the sewage is already stale and the solids are much more evenly intermixed. The first stage of purification, which depends so largely on the action of anærobic micro-organisms in the sewage itself, has already commenced in the larger sewers before the sewage reaches the outfall; and the arrangements necessary for the completion of the anærobic stage of purification at the Works are consequently to some extent simplified.

The Ventilation of Sewers

Much controversy has been expended on the question of what is the best method of ventilating sewers, and numerous processes have been patented for deodorising, disinfecting, or cremating sewer-air.

From what has already been said in these lectures, it will be rightly inferred that there is danger to the public health from the breathing of air mixed with the gases or emanations from sewers, and that precautions are necessary to obviate these dangers by minimising, as far as possible, the escape of gases from the sewers, or so to regulate their outflow that the points of escape are where least injury is likely to be done.

It would, no doubt, be best for the public health if all sewer gases could be bottled up in the sewers, and not allowed to escape into the general atmosphere at all, except after cremation in a furnace, or high above all inhabited places. This, however, is a counsel of perfection as regards gravitating sewers. One of the advantages of the Liernur pneumatic system of sewage removal is that there is no escape of any air from the Liernur sewers, as the induced vacuum in these pipes would, in the event of leakage, cause

an inrush of air from outside the pipe, and no air ordinarily escapes from within.

As is now very well understood in regard to gravitating sewers, it is neither possible to bottle up their aerial contents, nor feasible to draw all the air in an extensive system of sewerage to any one or more selected places. Air must enter and leave the sewers in very continuous fashion, and at many places, in obedience to the natural forces exerted by the alternations in the flow of sewage, the varying levels of the sewage in the sewer, the perflating or aspirating action of the wind, the varying temperatures inside and outside the sewer, and the barometrical changes in pressure of the external air. If no openings are made into sewers which are otherwise more or less air-tight, the points of ingress or egress of air will be through the nearest road-gullies or the house-drains communicating with the sewer. The condition of affairs thus arising would probably be worse than if carefully chosen ventilating openings to the sewers were provided. The men, also, who have to enter the larger sewers for purposes of cleansing, flushing, or repairs, must be provided with a respirable atmosphere; and the dangers of their calling would be substantially increased if no ventilators of any kind were provided.

The system now in favour by most borough engineers of ventilating the sewers by surface roadway gratings, combined at places with independent shaft standards, or shafts carried up to the roofs of adjoining houses, appears to best meet the difficulties of a rather difficult problem. For the dead ends of sewers, or in narrow courts and passages, where surface roadway gratings might very possibly be productive of nuisance, ventilating shafts are provided, and it is usually found that these sufficiently ventilate the sewers without causing offence.

If steam and very hot liquids are prevented from passing into the sewers, and if chemical wastes, productive of sulphuretted hydrogen or other deadly gases, are also excluded, there seems to be no special necessity in well-constructed modern sewers, laid with sufficient gradients, to do more in the way of ventilation than provide sufficient openings to the air for the necessary interchanges between the outer atmosphere and the air of the sewers, which depend upon the natural forces already alluded to. On the other hand, sewer ventilation is a most difficult and troublesome problem, if the sewers receive much hot or easily decomposable waste liquors from factories, which set up fermentation in the sewage with the disengagement of offensive or dangerous gases ; or if the sewers are old, badly constructed, or laid with very flat gradients, so that much sediment accumulates, which readily enters into decomposition. Under these circumstances, sewer ventilation is almost an impossibility, as the air which escapes is almost certain to create nuisance, somewhere or another, by reason of its offensiveness. To obviate the local nuisance so caused, attempts have been made to deodorise the sewer-air by passing it through trays containing animal charcoal, or through special forms of deodorising apparatus ; but all such appliances have been either found ineffective in practice, or too costly and troublesome to maintain in proper working condition. The cremation of the sewer-air has also been attempted by extracting it through special forms of gas flame, by which the air becomes highly heated ; but here again the cost of upkeep and maintenance, and the dangers of the coal-gas escaping, and finding its way into the sewers, have been successful in preventing more than experimental trials of this method.

The proper remedies for offensive sewers would appear

to be the reconstruction, on modern lines, of those that are old, worn-out, and liable to sedimentary deposit, and the prevention of the introduction of steam, very hot liquids, or chemical wastes into the sewers, which cause undue gas production.

Sanitary authorities should certainly be dissuaded from adopting any sewerage scheme which involves very flat gradients for many of the sewers. In the interests of public health, the sewage should be borne rapidly away from the houses and town, and this desideratum cannot be attained with a system of flat sewers. The aim to be strived for is a comparatively rapid flow of sewage in all branch and tributary sewers receiving house-drains, whilst a very much slower rate of flow in the outfall sewer is permissible, to allow time for the commencement of those anærobic transformations of the solids of the sewage which constitute the initial stage of purification.

If, on the other hand, the rate of flow in the branch and tributary sewers is very sluggish, there is not only that deposition of organic sediment, and its rapid putrefaction, which causes the evolution of offensive sewer-gases, but the anærobic and putrefactive changes in the bulk of the sewage may be overdone, with the result that when the sewage arrives at the outfall it is liable to be more highly septicised than is requisite for subsequent purification, and the nitrification of the ammonia and organic nitrogen in the filters may be in some degree inhibited.

Sanitary authorities of low-lying, flat towns should at the outset face the cost of installing pumping machinery to raise the sewage to the outfall, if found necessary to the proper laying of all street sewers with self-cleansing gradients. The additional expense so incurred would be amply repaid in future years, by the freedom of the town from

nuisance and the better safeguarding of the public health that will inevitably ensue. The system of raising the sewage from the tributary sewers by air-compression and automatic sewage ejectors, the invention of the engineers Messrs. Shone and Ault, has had excellent results in many places where it has been applied, and has enabled the local sewers everywhere to be laid with proper gradients, so that the sewage is carried away from the neighbourhood of habitations in a fresh and undecomposed condition.

It has been proposed that the sewers of a town should be entirely ventilated by means of shafts carried up adjoining houses, and that all surface roadway gratings should be closed. The balance of opinion is, however, against this proposal; first, because the efficiency of the ventilation would be impaired by the greater obstruction to the passage of air from friction in the lofty pipes and shafts, which also are frequently bent at an angle; and, secondly, because, unless the ventilating shafts are placed with the greatest care, there would be a danger of foul air entering houses through windows and chimneys. Such shafts would be carried from the crown of the sewers; but it has also been suggested that where house-drains are disconnected from the sewers, the sewer should be ventilated by a pipe carried up outside the house from the sewer side of the disconnecting trap. The same objections as described above are also valid in regard to this proposal; and, in addition, it is often overlooked that, owing, in many brick sewers, to the house-drains entering near the invert, and not near the crown of the sewer, whenever the liquid in the sewer is running above the level of the house-drain connections owing to heavy rainfall—and ventilation of the sewer is most necessary to provide an exit for the displaced air—the house-drains will be useless for this purpose. It seems to

me that there are many objections to these proposals for abolishing surface roadway gratings; and that, although the latter are often objectionable, they do, at any rate, often afford evidence of a condition of things in the sewer below which requires remedying. Their complete abolition might lead to neglect on the part of municipal authorities to maintain their sewers in that state of efficiency which the public have a right to demand, and which is necessary in the interests of health.

THE DISPOSAL OF SEWAGE

It will be unnecessary to discuss the question of whether sewage should be purified before discharge into streams and water-courses, as this has long ago been answered in the affirmative ; and it is now an established maxim in sanitary administration that crude sewage should never be allowed to flow into non-tidal waters, and may only be discharged into the sea or estuarial waters if there is no likelihood of damage being done to fisheries or oyster beds, and if the discharged sewage is certain to mix rapidly with large volumes of sea or estuarial water, and is not in danger of being carried along the sea fronts of coastal towns, where solid floating matters might be deposited on the foreshores.

The purification of sewage has been the subject of an immense amount of investigation, experimentation, and discussion during the past forty or fifty years ; but we need only consider at the present moment the chief methods which have survived the tests of actual practical application, and which are more or less in use at the present day. These are (1) *Precipitation* ; (2) *Surface irrigation of land*, with which is usually combined, (3) *Filtration through land*, and (4) *Bacterial treatment* by septic tanks and artificial bacteria beds, which last include intermittent contact-beds, and continuous or trickling filter-beds.

It will first of all be necessary to consider briefly what constitutes sewage. The sewage of all communities of persons in this country is water, containing, both in solution

and suspension, organic and inorganic matters of various kinds. These are derived from human excreta, chiefly discharged from inhabited houses and work-places; from animal excreta, received from stables, cow-sheds, slaughter-houses, and the surface washings of streets and roads; from the slop and kitchen waste waters of houses, and from the waste liquids of the various manufacturing processes carried on within the boundaries of the district sewered.

The sewage of one town or community of persons differs from the sewage of another town in a great variety of ways; and there are probably hardly two towns in this country of which the sewage presents the same average composition. These differences are due (1) to varying proportions of water-closets and dry (pail or midden) closets in different towns; (2) to the varying amount of water supplied per head of the population; (3) to the varying social habits of the population as regards the use of water in baths and washing; (4) to the proportional amount of rainfall finding its way to the sewers from roofs, yards, and street surfaces; (5) to the varying amounts of subsoil water which enter the sewers, where the sewers are not water-tight; and lastly (6) to the nature of the industries carried on in the town, and the amount and nature of the liquids which are discharged as waste waters from the industrial processes.

Broadly speaking, the towns of this country may be divided into *residential*, where the sewage is chiefly of the house or domestic variety, and *manufacturing*, where large quantities of factory waste waters of a special kind often give the town sewage a characteristic feature. But, as may be readily understood, there are a great many places of mixed residential and manufacturing nature; and then, again, each manufacture has its own special class of waste

product, so that the possibilities of variation in the composition of the mixed domestic sewage and manufacturing waste residues are almost endless.

Not only do the average compositions of the sewage of different towns differ from each other, but in each town the character of the sewage varies from season to season, from day to day, and even from hour to hour, according to the amounts of rainfall, the amounts of subsoil water entering the sewers, the existence of seasonal trades amongst the town's industries, the proportionate use of sanitary apparatus at certain hours of the day, and the times of discharge of the largest volumes of factory waste water into the sewers.

It is evident, then, that not only is sewage a very complex liquid, but that the nature of this liquid varies very greatly in different towns, and varies even in the same town from season to season, from day to day, and even from hour to hour; although, in the case of the sewage of any one town, the variations will be chiefly in the direction of the greater or less dilution of the sewage constituents with clean water.

The problem, therefore, of satisfactorily purifying the sewage of towns is one of unexampled complexity, as each town will have its own particular problem to solve; and although there are in respect of purification principles of general application, to which all the different varieties of sewage more or less conform, yet each particular case requires particular study and attention, if a successful result, *qua* purification, is to be attained.

Broadly speaking, we may describe sewage as consisting of water containing *organic matters in suspension and in solution*, and *inorganic or mineral matters in suspension and in solution*. Purification is concerned with the organic matters of sewage; the mineral matters are incapable of

putrefactive change and are inert, and no other steps are required in dealing with them than to separate as much as possible of the mineral grit and road-sand from the sewage, as it enters the works, by means of detritus tanks or catch-pits.

The organic matters are either nitrogenous or non-nitrogenous (carbonaceous), and are for the most part capable of fermentative change or putrefaction, with the production of more or less offensive compounds of complex constitution, which are finally resolved into the simpler residues—ammonia, nitrites, nitrates, carbonates, etc., and the gases CH_4, CO_2, N, H, H_2O, H_2S. These fermentative and putrefactive changes are brought about by bacteria, which are abundantly present in sewage and in surface soils, and which attack dead organic matters, assimilating the pabulum essential for their growth and propagation, at the same time undergoing enormous multiplication in numbers.

It is now usual in discussing the rôle of these bacteria, as purifiers of sewage, to classify them as *anaerobic* and *aerobic* organisms, according as to whether they live and grow in liquids from which oxygen is absent or is present; but there is also a class which are called *facultative anaerobes*, which can be either anaerobic or aerobic, according to the nature of the material in which they grow. This class comprises the greater number of the species which are concerned in the purification of sewage, the obligatory anaerobes being few in number. It must be understood that putrefaction is not the special rôle of any one of these particular classes of bacteria, as both anaerobic and aerobic fermentation may proceed both with and without the production of offensive compounds. A special feature, however, of the work of the anaerobic microbes is that organic matters in

suspension in the liquid are brought into solution as a preliminary to further action, and highly complex molecular bodies of stable composition are rendered unstable by rearrangement or alteration of their molecular elements, so that they are subsequently much more readily attacked by the aerobic organisms, which do their work in the presence of oxygen. This condition of instability is very largely brought about by hydrolysis, which signifies a chemical breaking-down of the complex organic molecule, by combination with the hydrogen and oxygen elements of the molecule of water.

In other words, nitrogenous organic matters which have been subjected to anaerobic change are rendered more susceptible to the nitrifying organisms on which ultimate purification so largely depends. Thus, it would appear that cellulose, which is a highly stable compound, is prepared in this way by anaerobic organisms for subsequent oxidation. A considerable proportion of the work of all these bacteria on complex organic matters is probably effected by the *enzymes*, which are elaborated by the bacteria in their life processes. These enzymes are non-living ferments, which, without being themselves broken up in the process, are able to resolve complicated organic molecules into simpler, more soluble, and more diffusible bodies.

It is now recognised that, whilst all the organic matters in sewage are liable to attack by bacterial organisms, and are consequently by these means reduced to the simpler forms of matter which are non-putrefiable—with the production of that desideratum, a non-putrefiable effluent—yet the organic matters in solution are much more readily and quickly decomposed in either land filters or bacterial beds than are the organic matters in suspension. For the destruction of these solid particles, the element of time is

necessary, and their accumulation on the surface of land, or in the top layers of bacterial beds, causes clogging and loss of action, with diminished efficiency in the purifying powers of the filters.[1] It follows, then, that there is an advantage to be obtained by the liquefaction of the suspended solids in the sewage, unless other means can be taken to effect their elimination prior to application of the sewage to land or bacterial beds.

The problem of the purification of sewage has been very largely considered from the point of view of the resolution of its contained organic constituents into simpler residual compounds, so that an effluent might be obtained which was itself non-putrefiable, and, in consequence, was not subject to any secondary fermentation after discharge from the effluent outfall.

This was a very natural point of view for those who were endeavouring to purify our rivers and to prevent the nuisances that resulted from the discharge of untreated sewage into water-courses; but the problem of sewage purification has now been carried further, for it is now ascertained that the really dangerous elements in a sewage effluent are not the dead or decomposing organic matters, but the living microbes which such effluent contains. This consideration is naturally of the highest importance, if the stream receiving the sewage effluent is used below the point of discharge as a source of water-supply. We shall see, later on, what effect the various processes adopted for the

[1] Suspended organic matters which are in colloidal form seem to exert a specially clogging effect upon filters composed of fine- or medium-sized material. The amount of such colloidal matter is frequently somewhat larger in a septic tank liquor than in the crude sewage before it enters the septic tank (fifth *Report, Roy. Com. on Sewage Discharge*, p. 44).

treatment of sewage have upon the bacterial flora of the crude article.

Precipitation Processes

As already said, sewage is a liquid of very variable composition; but for the purpose in view we may assume a sewage of average composition, such as that given by the Rivers Pollution Commissioners in their first Report (1868) for water-closeted towns. In 100,000 parts by weight of this average sewage there are 117 parts of total solids, of which 72 parts are in solution, and 45 parts are in suspension. Of the latter 24 parts are mineral matters, and 21 parts are organic (= 18 per cent. of the total solids). The Royal Commission on Sewage Discharge in their fifth Report (1908) think that, on the average, domestic sewage may be taken as containing 35 parts of suspended matter per 100,000 in dry weather.

The mineral matters in suspension are heavier than the organic, and when the sewage is brought to rest in settling tanks, they fairly rapidly settle down to the bottom of the tank. The organic matters are less easily deposited as sediment, and to hasten their settlement small quantities of chemicals, such as lime, sulphate of alumina, alumino-ferric, or protosulphate of iron are added to the crude sewage: hence these substances are known as precipitants. It is possible in this way to deposit the suspended matters as sewage sludge at the bottom of the tanks, and to obtain a highly clarified effluent containing very little suspended matter.

Precipitation processes do, therefore, eliminate from the sewage those matters which cause special difficulty, where an attempt is made to purify unclarified sewage on land

or in bacterial beds. But these processes do not furnish an effluent fit to discharge into a stream, as the dissolved constituents of the sewage are but little acted upon in the precipitation tanks; and not only is the clarified effluent putrescible and liable to secondary fermentative changes, unless diluted with a proportionally large volume of clean water, but it also contains practically nearly all the valuable manurial constituents of the raw sewage, and has, besides, a bacterial flora which is practically that of the latter.

The sludge, also, deposited in the tanks presents difficult problems of its own. It contains about 90 per cent. of water; it takes a long time to dry if exposed to the air; and, being putrescible, it creates a nuisance whilst drying; whilst its compression into sludge cake by filter presses, actuated by air-compressor machinery, is a tedious and costly process, and the cake produced is of such low manurial value that it commands little or no sale as a marketable product. If land is available, the partially dried sludge may be dug into and incorporated with the soil; and this appears to be the best method of dealing with it.

Precipitation processes, however, still have their advocates as preliminaries to further treatment on land or in bacterial beds; and in cases, especially, where the sewage contains acids or pickling liquors, the use of lime or other salts to correct acidity, or to throw down compounds which are inhibitory to the bacterial processes of purification, is one of undoubted advantage.

Land Treatment or Artificial Bacteria Beds

For many years land treatment was regarded as the only proper method of purifying sewage; and there are still many who think that this method, when applied

under favourable circumstances, affords the best solution of the difficulty. The first of the Royal Commissions appointed to inquire as to the best mode of distributing the sewage of towns reported in 1865 that "the right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided." Until comparatively recent times, also, it has been the practice of the Local Government Board to require, save in exceptional cases, that any scheme of sewage-disposal for which money is to be borrowed with their sanction, should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream.

It will be impossible in these lectures to enter into any lengthy discussion of the controversial aspects of the question of land treatment as opposed to artificial bacteria beds, but the essential points which have been ascertained in practice and are more or less uncontroversial, may be summarised briefly as follows :

Advantages claimed for Land Treatment.—It is said that the soil, and especially the surface soil, is the means provided by nature for the purification of all the organic waste matters produced on the surface of the earth. Hence the dictum, "The rain to the river, the sewage to the soil." Purification is effected on the land partly by surface flow and oxidation, but to a greater extent by filtration through the upper layers of the soil, which contain more or less abundantly those bacteria into whose rôle as sewage purifiers we are now obtaining some insight. The land is, therefore, a mechanical filter for the separation of suspended matters from the sewage, and also a natural bacterial bed, where the processes of bacterial purification may go on in a natural manner.

Crops also may be grown on sewaged land, or fallow land may be fertilised by sewage, prior to the growth of crops; and thus it is not only possible to recoup, by the sale of crops, some of the cost incurred in the preparation of the farm, but the agencies of growing plant life are also enlisted in the work of purifying the sewage.

On the question of the purity of the respective effluents from land treatment and artificial bacterial beds, no general comparisons can be made, as the conditions under which sewage farming is undertaken, and the methods of laying out and working bacteria beds, differ so enormously amongst themselves; but it would appear to be the fact that under the most favourable conditions, with land of the best quality and with sewage applied in exactly the right proportions, with proper periods of intermittency, effluents are obtained of a very high degree of chemical purity such as are not by any means of general occurrence with artificial filters.

On the subject of the bacteriology of sewage effluents, the work of Dr. Houston for the Royal Commission on Sewage Discharge affords most interesting reading (second Report, 1902). He found that the effluents from septic tanks, intermittent contact beds, continuous filtration beds, etc., contain an enormous number of bacteria, even although there is some reduction of their numbers in the effluent as compared with the crude sewage. The different kinds of bacteria, and their relative abundance, appear to be very much the same in the effluents as in the crude sewage. As regards undesirable bacteria, the effluents frequently contain nearly as many *B. coli*, proteus-like germs, spores of *B. enteritidis sporogenes*, and streptococci as crude sewage. The effluents, then, must be regarded as nearly, if not quite, as dangerous as raw

sewage; and Dr. Houston calls especial attention to the presence of streptococci, which are apparently even more delicate and easily destructible than typhoid bacilli, so that their presence in any number in an effluent seems to indicate the possibility or probability of the enteric fever bacillus also surviving under similar conditions, and, in general, would lead to the inference that the biological processes at work were not strongly inimical, if hostile at all, to the vitality of germs of pathogenic sort. These effluents of bacterioscopic impurity have often attained a good chemical standard of purity; so that it seems probable that the passage of the sewage through artificial bacteria beds is not nearly so effective in arresting bacteria of sewage origin as it is in reducing the amount of putrescible and oxidisable matter in the sewage.

On the other hand, Dr. Houston found that with land of proper quality, and by intelligent management, it was possible to obtain effluents of remarkably good bacteriological character—in some few cases so good that, apart from a knowledge of its source, the effluent might actually be regarded as a potable water of more than average quality. This result would be due to the more compact soil acting much more efficiently as a mechanical filter for germs than does a highly porous bacteria bed, and also to the length of time that the sewage remains in contact with the soil interstices, allowing the sewage bacteria to decline in numbers *pari passu* with the reduction in organic impurities. It must also be remembered that the amount of sewage applied to land is ordinarily very much less in proportion to area than in the case of artificial filters, so that each unit of filtering material receives a much smaller dosage of sewage.

Artificial Bacteria Beds

The stimulus to provide an alternative method to land treatment was created by the difficulties that very constantly arose when it was proposed to acquire land for sewage treatment, and also, after the sewage farm had been bought and laid out, during the processes of its practical working. As soon as the researches of Warington, in 1882, had demonstrated the part played by soil bacteria in the nitrification of organic matters, the way was opened for an attempt to copy, and, if possible, to improve upon the methods provided by nature for the purification of waste matters upon land.

The advocates for artificial bacterial beds point to the following difficulties which so often beset the path of the sewage farmer:

(1) The difficulty in obtaining suitable land of sufficient area in the near neighbourhood of large towns, and in the particular locality which is the natural point of discharge for the gravitating sewers of the sewered district. The land must be suitable for sewage treatment, because uniformly successful results can only be attained when the land is naturally fitted for sewage treatment. Consequently, heavy, cold clay, or other impermeable soils, where there is but little percolation, and the major portion of the purification is due to surface flow and air exposure, are considered undesirable. So also are bare chalky soils, peaty soils, very loose gravels, and sands without any retentive top surface, and water-logged soils in which there is no natural drainage.

The area of land required for sewage farming is enormously greater than that required for artificial bacteria

beds. The following figures represent approximately the areas of land required.

Sewage Farms with suitable Soil, e.g. a rather retentive loamy or alluvial top soil with porous, gravelly subsoil, and good under-drainage. When crude sewage is applied to such land, it can take 4,500 gallons per acre per diem = 150 persons of the population to each acre.

Ditto.—When the crude sewage is precipitated, and the clarified effluent only is applied to the land, it can take 15,000 gallons per acre per diem = 500 persons to each acre.

Sewage Farms with least suitable Soil, e.g. heavy clay lands, where there is little percolation, and surface flow must be largely relied upon. When crude sewage is applied to such land, it can take 1,500 gallons per acre per diem = 50 persons to each acre.

Ditto.—When the sewage is precipitated, and the clarified effluent is applied to the land, it can take 3,000 gallons per acre per diem = 100 persons to each acre.

Septic-tank Treatment, or Precipitation followed by Double Contact Beds or Percolation through Trickling Filters.—The filters can take from half a million to one million gallons per acre per diem = 16,000 to 33,000 persons per acre. But the area of land necessary for septic tanks or precipitation tanks must be added to the above.

In the opinion of the Royal Commission on Sewage Discharge, a greater rate of filtration can be adopted if the filtering material is arranged in the form of a percolating filter than if it is used in contact beds. The rate of filtration per cubic yard, in the case of percolating filters, may generally be nearly double that which is permissible in the case of contact beds.

There will, of course, be all grades between the sewage farm of very suitable soil and that of least suitable soil; but the excessive area of land required for farming will at once be realised from the above figures; and as the cost of land near towns is often high, and the cost of acquisition is generally largely added to by high legal and parliamentary expenses, it is perfectly intelligible that local sanitary authorities generally greatly prefer the less expensive scheme.

(2) Although crops are grown on a sewage farm, the only ones that will tolerate continuous treatment with sewage are Italian rye-grass, mangolds, cabbages, meadow-grass, and osiers; and the supply of these crops when grown on the farm very often exceeds the demands of the local markets. Then, again, the cultivation of the land to some extent interferes with the primary object of the farm—the purification of the sewage; so that the farm manager, having two objects in view—the production of revenue from the sale of crops, as well as the purification of the sewage—may to some extent be tempted to sacrifice the latter in order to show a satisfactory balance-sheet. There can also be little doubt that sewage farming requires greater intelligence and more experience and general knowledge of agriculture and farming than does the management of artificial bacterial beds, where the only object is the production of a satisfactory effluent without nuisance. The working under these circumstances tends to become more or less automatic and regular in routine, as the complications produced by the requirements of cropping are not encountered.

(3) On the question of the bacterial purity of the effluents, although, as already stated, the effluent from land of the best quality is much superior to that of an artificial bed,

it is only in a comparatively small proportion of sewage farms that such effluents are obtained. Dr. Houston reports that, generally speaking, the effluents from land, like those from bacteria beds, are not to be thought of as in a fit state to be turned into a stream supplying drinking water. They usually contain *B. coli*, spores of *B. enteritidis sporogenes*, and even streptococci. The bacteria peculiar to the soil are seemingly either absent, or present in small proportion only in these land effluents; the sewage bacteria everywhere predominate. It is, then, only a question of degree between the effluents from land treatment and bacteria beds, as both contain the elements of danger to the waters of potable streams into which they may be discharged.

On the whole, the idea that land is in all cases the best, because the most natural material for the treatment of town sewage has now been abandoned. Manurial matters should certainly, as far as possible, be returned to the land for its enrichment, and should not lightly be allowed to run to waste. It is not, however, one of nature's methods to fertilise the land with highly dilute liquid manure; and the excessive amount of water in sewage-applied manures must detract enormously from the value to the soil of the manurial constituents in the sewage. The natural method of manuring the soil is that which has been in use for centuries in China, and that was advocated by the late Dr. Poore—the application in detail of the more or less solid constituents of the excreta to the surface layers of the soil in accordance with the requirements of the crops for the time being occupying the land. The wholesale application of large volumes of water containing weak manures to land, whether the constituents of the soils are benefited or not in the process, is not nature's

method of replenishing the "bounteous earth," nor is it scientific agriculture.

Liability to Nuisance and Injury to Health incidental to Sewage Treatment

At this stage it will be desirable to consider this subject apart from the question of the purity of the effluent produced.

Generally speaking, it may be said that nuisance more generally results from carelessness and defective methods of working than from any inherent defect in the system, and that, with intelligent treatment and careful management, it is surprising with what little offence the treatment of so highly putrescible a liquid as sewage is, may be conducted.

In *precipitation processes* nuisance is more often engendered by the attempt to dry the sludge in shallow lagoons or sludge-pits in the open air than in any other way. Where the sludge is pressed into cake, the liquid oozing from the filter presses is very offensive, and should always be returned to the tanks for treatment. If this is not done, a nuisance is pretty sure to arise.

On *sewage farms*, the possibilities of nuisance arising are numerous. The land, or a portion of the land, may be overdosed with sewage, so that the top soil becomes clogged with sediment, and ponded sewage stagnates on the surface; or from want of proper periods of rest, the land may become sewage-sick, and incapable of exerting its purifying powers. The carriers may be allowed to become foul and offensive; and in a variety of other ways nuisance may result from defects in management, even where there

is a sufficiency of land and proper methods of applying the sewage to the soil are available.

There is no reason to suppose that sewage farming, as an occupation, is injurious in any way to the health of the workers, or that there is any deleterious influence exerted upon the health of people who live in the vicinity of a sewage farm, if ordinary care is exerted in its management. Nor is there any reason to attribute unwholesomeness to the produce of a sewage farm; but it is generally considered that market-garden crops should be grown on ridges, so that the leaves and stalks are above the level of the irrigating liquids in the trenches parallel to the ridges. Even dairy farming may be combined with sewage farming, if care is taken to prevent access of the cows to recently sewaged pastures.

As is now well known, there is a considerable risk to water-supplies where sewage is treated on the bare chalk, or on fissured chalk but thinly covered with weathered top soil. Under such circumstances "swallow holes" and fissures in the chalk may convey unpurified sewage for long distances to the water-bearing strata supplying deep wells. (See Dr. Copeman's report on Enteric Fever at Fulbourn Asylum; *Rept. M.O.L.G.B.* 1905–6; and paper by Drs. Richards and Brincker, *Trans. Epidem. Sect. Roy. Soc. Med.* vol. i., No. 6), and "Sewage Disposal on Chalk Soils" by Davies and Tyndale: *Journ. Roy. San. Inst.*, 1904, p. 643.)

In the modern installations of *septic tanks and bacterial beds* there is a greater liability to nuisance from effluvia than on well-conducted sewage farms, principally for two reasons, namely, (1) that the sewage treatment is concentrated on to a comparatively small area, and (2) that the highly septicised effluent from the septic tank is

necessarily offensive, giving rise especially to volatile effluvia when sprayed over the surface of trickling beds. Such effluvia are very often much complained of in the vicinity of the works.

The septic-tank treatment has been very largely adopted, because by it the sewage-sludge difficulty has been to a certain extent overcome. As previously mentioned, the anaerobic bacteria in the sewage at rest in the tank cause liquefaction of some of the solid suspended organic matters in the sewage,[1] and the deposit at the bottom of the tank is in consequence to a considerable extent a mineral residue of the nature of *humus*, and comparatively small in amount, so that removal of this deposit from the tank is only required at intervals. Putrefaction, although possibly not a necessary accompaniment of anaerobic action, is, as a matter of fact, in progress also in the tank, with the result that the effluent liquid is offensive. At the same time, purification of the sewage is also going on in the tank, as shown by the reduction in the tank effluent, as compared with the crude sewage, of the free and organic ammonias and oxygen-absorbed figures. The analyses of the gases given off from the surface of a septic tank also show that a considerable amount of the organic matter in the sewage, during its sojourn in the tank, must be completely broken down to produce these gases (CH_4, CO_2, N, and H).

The very excellent results obtained by Dr. George Reid (*County M.O.H. Staffordshire*), in his Hanley experiments, may here be quoted.

[1] The Royal Commissioners on Sewage Discharge (fifth Report, p. 229) estimate that with domestic sewage in septic tanks capable of containing the twenty-four hours' dry-weather flow, about 25 per cent. of the organic solids in the sewage are digested, *i.e.* brought into solution, or hydrolysed.

HANLEY EXPERIMENTS. ANALYSES OF SEWAGE AND EFFLUENTS

Mean Results in Parts per 100,000

	Solids in Solution.	Solids in Suspension.	Free Ammonia.	Organic Ammonia.	Oxygen absorbed in 4 hrs. at 80° F.
Crude Sewage ..	125·4	62·9	2·109	0·765	3·854
Septic-tank Effluent	105·3	4·4	1·820	0·270	1·725
Filter Effluent ..	112·8	0·7	0·037	0·030	0·252

The filter was a circular trickling filter, 4 ft. 6 in. in depth, made up of fine grain, saggar material from the potteries for a depth of 3 ft. 9 in. from the surface, graded to pass ½ to ¼ in. mesh. The rate of flow of the septic tank effluent over the filter was 200 gals. per sup. yard per twenty-four hours (= 968,000 gals. per acre).

It will be seen from these figures that treatment in the septic tank (after straining and subsidence in detritus and subsidence tanks—the total capacity of these tanks and the septic tank being a day's flow of sewage) effected a purification of 70 per cent. in the solids in suspension, of 14 per cent. in free ammonia, of 64 per cent. in organic ammonia, and of 62 per cent. in oxygen absorbed. Treatment in the bacterial trickling bed effected a purification of the septic-tank effluent of 84 per cent. in the solids in suspension, of 98 per cent. in free ammonia, of 89 per cent. in organic ammonia, and of 86 per cent. in oxygen absorbed. Whereas there was no nitric nitrogen in the crude sewage and tank effluent, the filter effluent contained 1·62 parts per 100,000.

These figures show what a very useful effect is produced

by septic-tank treatment, not only in the elimination of solids but also in reducing the soluble polluting constituents of the sewage.

Dr. Reid has also shown that in the case of a weak sewage, such as that of Hanley, the oxidising and purifying effect of a percolating filter of fine material consisting of $\frac{1}{8}$ in. particles is practically completed in the top layer of 1 foot or $1\frac{1}{2}$ feet from the surface of the filter, and that there is no advantage, but rather the reverse, in constructing fine-grade filters of greater depth. Allowing for the effluent drains and coarse material above them, he thinks the total depth of fine-grade filters need not exceed 2 ft. 6 in. As compared with the usual depth of 4 to 5 feet for percolating filters, the shallow filters would be much less costly to construct, and the saving in fall of two feet or thereabouts might be very important from the engineering standpoint.

It may be questioned whether the routine adoption of septic-tank treatment is always necessary or desirable. In the case of some towns, the sewage has already become septicised to a considerable extent by being locked up in outfall sewers or from very sluggish flow in large main sewers. In others, the sewage is very strong, or contains offensive waste liquors from breweries or other works, which render a further sojourn in a septic tank undesirable, by reason of the effluvia generated. It is also possible to over-septicise the sewage *quâ* purification, and to produce substances like amines or compound ammonias in strong sewages, which are injurious to the aerobic organisms of the bacterial beds.

It was at one time thought that domestic sewage which has passed through a septic tank, and become septicised, is more readily oxidised in its passage through filters than similar sewage which has been treated by chemical pre-

cipitation or by simple sedimentation; but the Royal Commission on Sewage Discharge do not agree that this necessarily follows.

There is still some difference of opinion as to whether septic tanks should be open to the air, or covered over by a light roofing or arched brickwork. There would certainly seem to be less danger of nuisance arising from covered tanks, as, with open tanks, even although ordinarily inoffensive, it happens that under certain atmospheric conditions foul odours are undoubtedly given off by the passage of the gases of fermentation through the scum covering the tank, and the latter forms an attraction for flies, which may cause annoyance to houses in the vicinity. On the other hand, with a properly managed system, it is surprising what little offence is caused under ordinary conditions by a well-scummed open septic tank, the scum appearing to have but little capacity of creating nuisance, if left undisturbed. On the whole, perhaps it may be considered, that where inhabited dwellings are in the vicinity of sewage works, say within a radius of a quarter of a mile, septic tanks should be covered over, to prevent the possibility of nuisance from effluvia and flies; but where the sewage works are well isolated, the necessity for covering in the tanks does not appear to arise. Something, however, depends upon the nature of the sewage to be treated; and, where this is very strong or contains offensive waste matters from breweries, tanneries, or chemical-works in relatively large proportions, it will generally be considered that it is advisable for the septic tanks to be covered over, although the nuisance resulting from this source is generally less apparent than that due to the secondary treatment of the septic-tank effluent.

With regard to the latter, the greatest nuisance is created

when the septic-tank effluent is distributed over trickling continuous filter beds by means of revolving sprinkler arms or of fixed nozzle distributors. In these forms of distribution a fine liquid spray is ejected as the sprinkler arms revolve over the beds or as the nozzles come into action; and this spray, like a fountain jet, has a considerable height to fall through the air before it reaches the surface of the bed. In this manner the air over the filter beds becomes impregnated with the volatile effluvia given off from the septic-tank effluent. There is in consequence not only an offensive smell generated in the neighbourhood of the filter beds, but the wind may carry the effluvia to a distance, and thus cause a nuisance in the neighbourhood outside the area of the sewage works. The distance to which such odours may travel has not been satisfactorily determined; but it is safe to assume that under favourable atmospheric conditions, such as occur when there is a gentle breeze, and the air is heavy and "muggy," with a falling barometer, such odours are perceptible half a mile at least to leeward of the filter beds. The influences exerted upon the health of the residents in houses within the zone of effluvia dispersal are no doubt similar to those created by other kinds of organic effluvia. The complaints of the inhabitants concerned usually refer to feelings of disgust and nausea, to sickness, loss of appetite, distaste for food, and at times to attacks of vomiting and diarrhœa. There can be no question that real hardships are at times entailed on the residents of a locality which is liable to invasion by the smells and effluvia given off from septic effluent sprinkler beds.

The methods of distribution of tank effluent over filter beds by means of elongated water-wheels, which, pivoted at the centre, roll bodily over the surface of a filter on

circular rail tracks around the circumference of the filter (Fiddian Automatic Distributor—Birch, Killon & Co.), or by travelling distributors, in which the water-wheels pass backwards and forwards over rectangular beds, are far preferable, from the point of view both of even and regular distribution of the effluent over the filter, and also of lessened likelihood of nuisance, to the revolving sprinklers and fixed-nozzle distributors. In the water-wheel distribution, the effluent falls in thin sheets, and has but little depth of air to traverse, the water-wheel distributor being close down on the bed, unlike the fountain sprays of the sprinkler and nozzle distributors. Consequently there is much less risk of effluvia being conveyed by winds to considerable distances.

It has been asserted that with the sprays and fountain-jet methods of discharging tank effluent over a filter-bed there is a risk of pathogenic organisms being present in the droplets of fine spray, which may be carried by the wind to neighbouring houses, and so originate disease amongst the occupiers. It is of course possible that such might occur; but, on the other hand, the dilution of the infective agent with pure air would be very great as the distance from the filter increased, and it is hardly conceivable that a poison so extenuated could originate disease by inhalation. In immediate proximity to the filter, the possibility of infection cannot be excluded.

In their recently issued fifth Report, the Royal Commissioners on Sewage Discharge, writing on nuisance from smell at sewage works, say (p. 195): "Septic-tank treatment is likely to be more offensive than chemical precipitation or simple sedimentation. During sludging operations (the removal of sludge) all tanks are usually offensive; but septic tanks—unlike other tanks—may give off sulphuretted

hydrogen, and probably small quantities of offensive organic sulphides at other times. By covering over septic tanks, and the feed channels to the filters, the risk of nuisance from the tanks themselves, during the period of working, is greatly lessened; but the liquor issuing from septic tanks contains a larger amount of sulphuretted hydrogen than other tank liquors, and its subsequent filtration may, therefore, give rise to more nuisance. The exposure of a foul-smelling liquid to the air is necessarily accompanied by risk of nuisance; and if such a liquid, in the process of distribution, is divided up into small drops or jets, it is obvious that the smell will be greatly intensified. For these reasons percolating filters are more likely to give rise to nuisance than contact beds. . . . In some cases, septic tank liquor can be treated upon percolating filters without much risk of nuisance; but where the liquor is derived from a strong domestic sewage, or a domestic sewage containing brewery or tannery waste, and especially if it is sprinkled or sprayed upon percolating filters, serious smell may occur in the neighbourhood of the works."

The Commissioners also observe that in the whole of their experience with contact beds, in only one case did they observe any appreciable nuisance to arise after the liquor to be treated was in the bed. In this case, moreover, the smell was due to over-working, for it practically disappeared when the beds were given a short rest. There was, however, almost always local smell from the channels or feed troughs delivering to a contact bed, when the liquid to be treated was offensive; and in some cases there was smell when a primary bed was discharged.

The Commissioners draw attention to an important point, which is sometimes lost sight of, namely, that although the surfaces of contact beds are rich in insect life, it is

unusual to see many flies on the beds, whereas percolating filters of coarse or medium material generally swarm with them.

Dr. Gilbert Fowler is of opinion that the chief source of the white-winged fly, so common on many coarse percolating filters, is the accumulation of undigested suspended and colloidal matter with gelatinous growths, which occur immediately below the surface of high-speed percolating filters. In a contact bed, on the other hand, the colloids are fairly evenly distributed throughout the mass of the bed, and such areas of imperfect oxidation do not occur if the bed is properly worked. The larvæ of flies and gnats find favourable conditions of growth in the colloidal and gelatinous masses on the surfaces of percolating filters; whereas in the contact bed, the more equable distribution of the colloidal matter, and the periodical complete filling of the bed, are unfavourable to insect life.

On the whole, we may conclude that, to obviate nuisance from smell, strong domestic sewages, or sewages containing offensive wastes from breweries and tanneries, should not undergo septic-tank treatment, with subsequent sprinkling of the offensive tank liquor over percolating filters. The treatment of such sewage by preliminary precipitation with lime, preparatory to the subsequent passage of the clarified effluent through filter beds, is the system which in such cases is least likely to produce a nuisance.

With regard to the use of lime as a deodorant, the Commissioners on Sewage Discharge found that the offensive character of Dorking septic-tank liquor could be destroyed by the addition of three grains of lime per gallon. The liquor so treated could, after a short period for settlement, be filtered at a considerably increased rate. The plan of treatment favoured by the Commissioners is the passage of

septic-tank liquor through tanks of capacity sufficient to hold about a quarter of the day's flow, with the addition of two to three grains of lime per gallon to the tank liquor, sedimentation occurring in these tanks. By this method of treatment the Commissioners say that the suspended solids in the septic-tank liquor are materially reduced, a considerably larger quantity of the liquor can be treated per cube yard of filter, and the offensive character of the liquid is largely destroyed.

Where the sewage is of weak domestic character, and contains a mixture of trade wastes, especially if iron salts are present, treatment in septic tanks, and filtration through percolating filters, are not likely to produce any nuisance (fifth Report). Between these two extremes there are all varieties of sewage, and the appropriate treatment, having regard to the prevention of nuisance, must be largely determined by local conditions.

Mr. Dibdin, one of the pioneers of the bacterial purification of sewage, has always been of opinion that the chief work in purification should be done by the aerobic organisms, so as to avoid as far as possible the septic fermentations accompanying anaerobic changes. The Sutton beds devised by him, and laid down as long ago as 1896, consisted of coarse primary, and fine secondary, contact beds, the screened sewage being passed into the coarse contact beds without any septic-tank treatment. Some 60 per cent. of the solids of the sewage were liquefied in these coarse contact beds, and successful results in purification were obtained; but the capacity of the beds for liquid was in time very seriously reduced by the deposition of sludge, especially in the upper surface layers of the bed; and it eventually became necessary to allow the sewage to settle in sedimentation tanks before it was discharged into the

coarse beds, so as to avoid the "sludging up" previously experienced.

Now, the short period of an hour or two's rest in a coarse contact bed does not septicise the sewage to anything like the same extent as the much longer period of detention in a septic tank (twelve to twenty-four hours, or longer, according to circumstances); and the liquefaction of the suspended organic solids of the crude sewage will probably here be due to anaerobic action, assisted by aerobes of the kind that can act in association with the anaerobes, under the conditions that obtain in working the bed. At any rate, it has been found, under the methods of working primary coarse contact beds, that the sewage is not putrefied to anything like the same extent that it is by septic-tank treatment, and that there is very little tendency to the production of nuisance in the further treatment of the effluent from these beds. If, however, the beds are overworked, aerobic agencies are discouraged, and septic effluents are produced. Dr. Gilbert Fowler is of opinion that in contact beds, broadly speaking, oxidation takes place alternately by nitrification during the "standing-empty" period, and denitrification during the "standing-full" period. The amount of oxidation effected in the bed cannot, therefore, be altogether estimated by the amount of nitrates present in the effluent.

Dibdin's Slate Beds

Mr. Dibdin has now modified the system of coarse contact in beds of coke or clinker, by introducing slate beds (Devizes and High Wycombe). In these beds, refuse slates from the quarries are laid in horizontal layers $2\frac{1}{2}$ inches apart, and the beds are filled with crude unscreened sewage, and

allowed to remain full for two hours, then emptied, and given two hours' rest before again filling. Enough air appears to be retained (trapped) in these beds—probably on the under-surfaces of the slates—to allow aerobic action to go on when the sewage is at rest in them. Solids are deposited on the top surfaces of the slates, and the beds are said to be fully matured when this deposit attains a thickness of a quarter of an inch in depth. Mr. Dibdin's description of this deposit is as follows: "The bulk is a gelatinous mass of bacteria in zooglœa form, in which are mixed the cellulose fibres and grit of the sewage, and other matters which are refractory or indigestible. The gelatinous mass breaks away at the edge of the slates, and is discharged with the effluent at the rate of some two grains per gallon averaged over the year, a quantity Dr. Gilbert Fowler calls a 'trace.' From a strong sewage, such as that of Devizes, the average deposit per filling may be taken as about one-fortieth of an inch in depth. These fresh sewage solids form food for the organisms in the worked-out 'earth' beneath them, and are rendered inoffensive by the digestive processes of the animal organisms, which, as is well known, attack the less stable portions first. Ultimately, the new deposit is merged in the gelatinous mass, and the residue is discharged with the effluent as described" (*Public Health*, August 1908).

The maintenance of the aerating agencies is provided for by the rest periods, when the slate beds are empty. During these periods the aerobes continue their action on the solids deposited on the top surfaces of the slates. The effluent is highly charged with aerobic bacteria, and is not only quite inoffensive, but is in a suitable condition for subsequent treatment in secondary beds or on land.

The sewage of Devizes is excessively strong and foul,

owing to numerous piggeries, bacon factories, and slaughter-houses in the town. It is said often to contain 400 grains of suspended matters per gallon, and in other respects is of an average strength six times that of London sewage. When the Devizes sewage was chemically treated for precipitation, not only was there very considerable nuisance in the neighbourhood of the works, but a large quantity of sewage sludge was produced (1,700 tons of pressed sewage cake in two years and a half). In two years and a half of slate-bed treatment, fifty tons only of an inoffensive mould or earthy residue have been collected from the effluent channels of the slate beds, and from the surface of the fine clinker beds used for the treatment of the slate-bed effluent.

The following further particulars as to the Devizes slate beds are obtained from a paper by Major G. E. F. Stammers in the *Journal of the Royal Army Medical Corps*, November 1908:

"Devizes has a population of 6,500, and an average dry-weather flow of sewage of 250,000 gallons daily. There are eight slate beds, each being 65 ft. by 45 ft. and 4 ft. deep, and two storm-water beds, each 80 ft. by 68 ft. and 4 ft. deep. There is a six-inch space between the last layer of slates and the floor of the tank. The sewage is not screened prior to entering the slate beds, except after rain. The top layer of the coke-breeze beds, which receive the slate-bed effluent, is turned over and broken up to the depth of twelve to fifteen inches every ten days on an average. The last portion of the discharge from the slate beds, practically consisting of humus, is not passed on to the coke beds, but goes on to a drying ground. Here the solids are allowed to weather, and they soon become friable and quite inoffensive. Judging by the albuminoid-ammonia

figure, 80 per cent. of the possible purification may be attained by treatment of the sewage of Devizes in the primary slate beds and secondary coke-breeze beds. The slate beds alone will give a purification of 25 to 30 per cent., which is practically very much what is ordinarily attained by septic-tank treatment."

The results obtained at Devizes appear to be very satisfactory, but further experience with other varieties of town sewage, and under varying conditions, is required before the question of the general applicability of slate beds as a preliminary to filtration can be placed on a settled basis.

Nearly all the authorities are agreed that in the biological purification of sewage it is distinctly advantageous to separate the stages of purification, because distinct classes of micro-organisms appear to be concerned in the primary hydrolytic changes (which, in the practical absence of oxygen, bring about the preliminary liquefaction of solid organic matters, and the resolution of organic matters in solution) to those engaged in the later oxidation processes whereby, with the aid of oxygen, the ultimate re-solution of the organic matters in the tank effluent are effected. There seems also to be a consensus of opinion that these distinct classes of organism exert their powers more effectually when separated from each other, and when working in the special environment suited to each class.

The difficulty, so far, has been that the anaerobic changes are associated with putrefactive decompositions, which in certain instances cause so much septicity as to give rise to nuisance, both in the septic tanks and in the subsequent treatment of the septic-tank effluent.

In the case of those sewages in which septic-tank treatment is liable to engender considerable nuisance, but in which such treatment is otherwise beneficial for the purpose

of producing a properly purified effluent, it would seem that there is scope for the application of some method by which anaerobic changes should be allowed to go on, but the putrefactive fermentations should be inhibited from proceeding to the extent of generating the foul-smelling products which cause the offensive effluvia. It appears certain that anaerobic changes can proceed without the accompaniment of much putridity, and it is possible that Mr. Dibdin's slate tanks may be successful in effecting the necessary anaerobic changes without producing septic effluents. The Royal Commissioners on Sewage Discharge inspected these beds at Devizes, and came to the tentative conclusion that primary beds containing large slabs of slate must be regarded more as preliminary settling or septic tanks than as contact beds. As to the feasibility of washing such beds out, or as to the amount of digestion of sludge which takes place in them, they were unable to express an opinion.

It would appear that further experimental investigation is required with sewages that are abnormally strong, or have already become septicised in the town sewers, or that contain foul-smelling wastes from breweries or tanneries, to ascertain in what way the necessary anaerobic changes can be made to take place without the accompaniment of associated putrefactive decompositions; or, if putrefaction has already set in before the sewage arrives at the works for treatment, in what way the sewage can most suitably be deodorised so as to interfere as little as possible with the changes necessary to the production of an effluent which is in a suitable condition for filtration in artificial beds.

The addition of lime to the septic-tank liquor, as suggested by the Commissioners, and sedimentation in settling

tanks, may be as efficacious as they say; but it involves the removal of the deposited sludge from the tanks, and introduces the same difficulty inherent to all precipitation processes which the septic-tank system is intended to obviate.

The Question of Effluents: The Chemical Characters of Sewage Effluents

We must now consider to what extent considerations of public health require that effluents from sewage treatment should be purified before discharge into streams or tidal waters.

Broadly speaking, a very great deal must depend upon whether, in the case of a stream receiving an effluent, the stream is one that is used as a source of water-supply below the point of discharge, or is not so used; and in the case of tidal waters, whether the point of the discharge of effluent is in the neighbourhood of oyster beds or mussel beds, or the circumstances are such that, even if such beds are remote, there may conceivably be danger to such beds under certain sets of conditions. Apart from these general considerations, it is obvious that local circumstances vary so enormously, and that in many cases there is such a complexity of collateral issues, that it is perfectly impossible to lay down any hard-and-fast rules applicable to all. Any adoption of general standards of purity at the present time would be attended with the greatest difficulties, involving possibly very considerable hardships and injustices in particular instances.

Speaking generally, it may be said that all sewage effluents should be so far purified by treatment that they display no tendency to secondary fermentation or putrefaction

processes, when kept undiluted at ordinary air temperatures. Much less should there be any fermentative change, when mixed with and diluted by the water of the stream or estuary into which they are discharged.

This tendency to secondary fermentation seems to depend less upon the absolute amount of putrefiable or oxidisable matter remaining in the effluent than upon the relative proportions of these matters to the fully formed basic nitrates in the effluents. With a strong crude sewage, even with the best kind of bacterial bed treatment, only some 90 or 95 per cent. of the organic impurities will have been converted into harmless inorganic elements, and the remaining 5 or 10 per cent. of these impurities may on analysis give figures for "organic ammonia" or "oxygen absorbed," which do not comply with some arbitrarily adopted standard of purity. Still, in such an effluent there may be a large reserve of basic nitrates, fully sufficient to provide by denitrification for the oxygen necessary to enable the aerobic organisms present in the effluent to react upon the dissolved organic impurities, and effectually prevent any further putrefactive change.

On the other hand, a dilute sewage may be very imperfectly purified by some process which is defective in principle or in practical application, and yet the effluent may pass the required standard of purity. Owing, however, to the very deficient nitrification that has resulted, there may be no reserve of oxygen in the effluent, with the result that given a high temperature or other adequate exciting cause, secondary putrefaction takes place in the stream, and a nuisance results.

It is of most importance, perhaps, from the point of view of nuisance, to have some standard for the suspended

matters in an effluent, as these matters may be quickly deposited when the effluent mixes with a large volume of nearly stagnant water, with the resulting formation of mud deposits, near the effluent outfall, which silt up the bed of the stream, and by undergoing putrefaction cause a nuisance in the locality.

The standard adopted by the Rivers Pollution Commissioners, appointed in 1868 in reference to sewage effluents, was:

Dry mineral matter	not to exceed	3 parts	by weight	in 100,000
Dry organic matter	,,	,,	1 part	,,	,,
Organic carbon in solution		,,	2 parts	,,	,,
Organic nitrogen	,,	,,	0·3 part	,,	,,

The standard, of recent years, accepted by the Lancashire and Yorkshire River Boards as provisionally requisite for effluents going into a stream not used for drinking purposes is:

Albuminoid Ammonia	0·14 part per	100,000
Oxygen absorbed	1·4 parts ,,	100,000

It is evident that there can be no one standard of purity, whether chemical or bacteriological, which is capable of application to the country generally; and it would be almost equally difficult to devise chemical and biological standards applicable to effluents as discharged into potable and into non-potable streams, or into estuarial waters with or without oyster beds on their foreshores.

The only avenue for advancement in this matter is to constitute River Boards, as recommended by the recent Royal Commission on Sewage Discharge, to be constituted the sole controlling authorities for the watershed areas into which the country should be mapped. The intimate acquaintance of these River Boards with local

circumstances and necessities would enable them to devise standards suitable for their districts which would be acceptable alike to sanitary authorities, manufacturers, and the general public.

The Royal Commission on Sewage Discharge in their fifth Report has gone carefully into the question of standards for sewage effluents (p. 217). The harm caused by allowing unpurified, or imperfectly purified, sewage to flow into rivers and streams may be placed, they say, under one or more of the following headings:

(1) The de-aeration of the water of the river, and consequent injury to fish. (2) The putrefaction of organic matter in the river to such an extent as to cause nuisance. (3) The production of sewage fungus and other objectionable growths. (4) The deposition of suspended matter, and its accumulation in the river-bed or behind weirs. (5) The discharge into the river of substances, in solution or in suspension, which are poisonous to fish or to live stock drinking from the stream. (6) The discoloration of the river. (7) The discharge into the river of micro-organisms of intestinal derivation, some of which are of a kind liable, under certain circumstances, to give rise to disease.

In the first place, the Commissioners are of opinion that the suspended solids of a sewage effluent should be reduced to a low figure before such effluent is allowed to escape into a water-course. On an average, two-thirds of these suspended matters in effluents from artificial filtration processes are volatile, *i.e.* organic; and such organic matters are practically always putrescible, and capable of taking up oxygen from water comparatively rapidly. So long as such solids are kept moving in oxygenated water, or in water containing nitrate in solution, they

will not give rise to nuisance from smell; but if allowed to accumulate in the sluggish reaches of a stream, they will ultimately form a black and putrid mud. For these reasons they consider that the limit for suspended solids in an effluent should be not more than three parts per 100,000—equivalent to two parts of *organic* matter in suspension.

As regards matters not in suspension, but in solution in the effluent, the Commissioners observe that the effect of an effluent upon a stream does not generally depend upon the absolute amount of organic matter contained in it, but rather on the nature and condition of that organic matter; and that the important thing to ascertain in examining an effluent is the extent to which the original organic matter has undergone fermentation. Thus, an effluent which is non-putrescible on incubation must already have undergone a satisfactory amount of fermentation; and not only will it remain stable when discharged into a stream, but it will also take up but little dissolved oxygen from the water into which it is discharged. The Commissioners think that an effluent which does not take up dissolved oxygen from the water of a stream more rapidly than that water can naturally re-aerate itself from the air, would be unproductive of nuisance, and would not injure fish life.

They therefore suggest the provisional adoption of a dissolved oxygen or aeration test for an effluent which has been first deprived of its suspended matters by filtration through filter paper, namely, That it should not absorb more than 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in twenty-four hours, 1·0 part by weight in forty-eight hours, or 1·5 parts by weight in five days.

It should be understood that these suggested standards are provisional, and for the guidance of local authorities as average requirements.

Nuisance may not only be caused in a stream by secondary fermentation of the organic matters in a sewage effluent, but the effluent may cause the growth in the stream of lowly vegetable organisms, which often give rise to nuisance and difficulty. Even the best effluents contain a certain amount of plant food in solution, and therefore tend to promote vegetable growths. In the case of a stream receiving well-purified and nitrated effluents these growths are green, from the presence of chlorophyll, and are unproductive of nuisance until they become detached and accumulate in sufficient quantities to give rise to nuisance from decomposition. In streams receiving imperfectly oxidised effluents, grey growths of the sewage-fungus order may arise, and tend to choke up the bed of the stream, at the same time causing an offensive nuisance when decomposition occurs. The Commissioners, however, are not at present in a position to state exactly what effluents will, and what effluents will not, cause objectionable growths in streams.

The Biological Characters of Sewage Effluents

The question of the biological purity of sewage effluents is an even more difficult one than that of chemical purity, as it is so intimately related with the life processes of the enteric fever bacillus, and of other disease organisms that are occasional inhabitants of water; such knowledge as we possess on this subject being scanty, and liable to revision with every advance made by bacteriological

knowledge in the isolation and identification of the pathogenic organisms concerned.

It will be unnecessary to recapitulate here what has already been said about the survival of *B. typhosus* in sewage, in sewage effluents, and in water. There can be no question that it behoves us to exercise extreme discretion in dogmatising on a subject which is so full of doubt and difficulty. Bacteriological research, on the whole, tends to show that *B. typhosus* is not a resistant organism, and that its destruction, after passage from the human body, is inevitable sooner or later, no matter what habitat it assumes. Epidemiology, on the other hand, suggests that the *Bacillus typhosus* is not always so easily accounted for as bacteriology would lead us to believe. The histories of numerous water epidemics and of shell-fish (oyster and mussel) outbreaks would seem to show that infection may be retained in sewage, in sewage effluents, and in polluted water for periods much longer than *a priori* on bacteriological grounds we could consider probable; or, of course, it may be that the *Bacillus typhosus* is not alone concerned in disease causation, and that there are other organisms involved, or at any rate other undetermined factors at work, which in association originate disease, but acting singly are powerless to affect the human body.

Even bacteriologists themselves will acknowledge that a biological standard founded on the relative abundance of *B. coli*, *B. enteritidis sporogenes*, or streptococci in a sewage effluent is only a very comparative test, and one only remotely suggestive of possible pathogenicity.

As we have already seen, with the exception of certain very high-class effluents from land treatment, the ordinary sewage-farm effluent and the effluents of all artificial bacterial-bed processes contain the bacterial flora of sewage

in great abundance. They must, therefore, be considered as but little, if at all, less potentially dangerous than discharges of crude sewage.

Is it feasible or desirable to require that such effluents should be sterilised before discharge into streams used for drinking water, or into estuarial waters where oyster layings are threatened by the discharge ? Bacterial beds being what they are, it is perfectly impossible that they can ever retain in their substance, or otherwise eliminate the bacterial organisms present in sewage. Should, then, land treatment be required in all such cases, with the view of sterilising the effluent from the bacterial beds, which is already sufficiently purified from the chemical standpoint; or, should the effluents be sterilised by disinfectants before being allowed to escape at the outfall ?

There can be no doubt that the effluent from a bacterial-bed process can be further purified by filtration through a sufficient area of land of suitable quality. Whether the organisms characteristic of sewage can be entirely eliminated by land treatment is very doubtful; but it is probable that their numbers can be very materially reduced in this way, and the possibilities of danger attaching to the sewage effluent be in corresponding sort diminished.

In the same way it may theoretically be possible to sterilise a sewage effluent by the addition to it of chemical disinfectants before its discharge into a stream. It is evident, however, that the choice of chemical disinfectants for such a purpose is a limited one, as any compound of a poisonous nature would be contraindicated if the stream is used as a source of water-supply; and there is also a possibility of injury to the fish in the stream from the use of substances which either are directly poisonous to them, or

which deprive the water of the oxygen necessary for their life.

For streams used as sources of drinking water the most suitable disinfectant for a sewage effluent would appear to be ozone, as this gas is non-poisonous and is the means of introducing into the water the oxygen which is essential for the oxidation of the organic matters in the effluent, and which is otherwise taken from the water of the stream with which the effluent mixes. The ozonisation of water-supplies with a view to the destruction of pathogenic microbes has been inaugurated in France, apparently with some success, and the ozonisation of the sewage effluent from a bacterial bed, with the object of destroying its contained sewage organisms, could possibly be undertaken, although the process might be a costly one.

In the *Journal of the Royal Sanitary Institute* for February 1909, Dr. Rideal contributes a very interesting article on "The Purification of Water by Ozone," with a description of the De Frise installation for the sterilisation by ozone of the filtered water drawn from the river Marne, at the St. Maur Municipal Waterworks, near Paris, the Marne being a stream which, although it receives a considerable amount of sewage pollution above the intake, is used as a supplementary source of supply to the spring water which is usually distributed to the city of Paris. It would appear that except for the very highest grade of sewage effluent—one which is well aerated, well nitrated, and comparatively free from oxidisable organic matters—ozonisation would be too costly a process, as so much of the oxidising power would be neutralised by oxidation of organic matters before any sterilising effect was produced. For such high-grade effluents as resemble in character a crude river

water rather than purified sewage, there may be a future for an ozonising process as a partial steriliser.

Where the sewage effluent is to be discharged into estuarial waters, the choice of disinfectants is a wider one. The use of liquids containing free chlorine for disinfecting purposes would here be permissible, as the estuarial water being a mixture of fresh and sea water will already contain chlorides in abundance; and there would be no reason to anticipate injury to fisheries from the addition to the effluent of calcium or sodium hypochlorite and other chlorine compounds in the amount necessary to produce the requisite quantity of available chlorine for sterilisation.

In the *oxychloride process* sea water, or water containing 10 per cent. of common salt, is electrically decomposed in an electrolyser having a large superficial area of electrical surface, which permits the use of a high density current at a low voltage. The resulting liquid contains 0·2 per cent. of available chlorine, chiefly in the form of hypochlorite of calcium.

From Dr. S. Rideal's experiments at the Guildford Sewage Works it appears that, when mixed with appropriate volumes of sewage effluents, the oxychloride solution very largely reduces the total number of organisms present in the effluent, and practically eliminates the *B. coli communis*. Thus 3¼ gallons of oxychloride per 1,000 gallons of secondary effluent, *i.e.* effluent from septic-tank treatment, contact beds, and streaming filters, is sufficient, after one hour's treatment, to reduce *B. coli* from 100,000 per c.c. of untreated effluent so that none could be found in the treated effluent.

It is claimed for this process that, whilst a sewage effluent cannot be actually sterilised by its means, yet organisms of intestinal origin can be so far eliminated as to render

the effluent admissible into a stream supplying potable water, or into waters containing oyster layings or water-cress beds. Oxychloride solution itself is non-poisonous in the strength obtained by electrolytic decomposition of salt water.

In some more recent experiments with oxychloride solution applied to septic-tank effluents, which are highly offensive, it has been found that a very satisfactory amount of deodorisation can be obtained, the odour of sulphuretted hydrogen being entirely removed by the oxidising action of the chlorine. At the same time, the addition of the small amount of oxychloride solution necessary to insure deodorisation of a septic-tank effluent, in no way affects the efficiency of any subsequent filtration. In fact, it aids the filtering process by tending to prevent the growths of grey gelatinous material that so often form on the top surface of filters receiving even a well-clarified tank effluent. Neither is the maturation of the filter bed in any way interfered with; that is to say, the growth of the nitrifying organisms in the interstices of the bed is not hindered. The use, too, of fine-grade filters is rendered possible, owing to the lessened tendency to the formation of clogging growths on the top surfaces.

Should it be found possible to install an oxychloride plant at a reasonable cost for dealing with offensive septic-tank effluents, the problem of preventing aerial nuisance without hindrance to the oxidising processes carried on in the filters would appear to have been satisfactorily attained; whilst it may possibly also by this means be found feasible to reduce the numbers of bacilli of intestinal type in the final effluents to insignificant proportions.

The above remarks apply more particularly to the sterilisation of effluents under the ordinary conditions of

dry-weather flow of sewage for which sewage works are designed. It is evident, however, that the sterilisation of the effluent from the ordinary dry-weather flow would be of but little practical advantage if storm-water discharges were allowed to pass untreated and unsterilised into the stream. Dr. Houston, in his Report to the Royal Commission on Sewage Discharge, says he regards storm water from the sewers as being "potentially as dangerous to health as normal crude sewage"; and Dr. Reid has pointed out in a paper read before the Royal Sanitary Institute (*Journ. Roy. San. Inst.* vol. xxiii.) that sterilisation, to serve its purpose, must be carried out not only on the dry-weather sewage, on the storm-water sewage equal to three times the dry-weather flow, which the rules of the Local Government Board require to be dealt with in the purification works, and on the storm-water sewage equal to six times the dry-weather flow which the same rules require to be treated on storm-water filters, but that it would also be necessary to sterilise the whole of the surplus storm water (over and above the six volumes of dry-weather flow) received at the purification works, and to place a sterilising plant on every storm overflow which exists in the whole system of sewers.

These, of course, are counsels of perfection, and absolutely impracticable under any ordinary conditions; nor could the sufficiency of the sterilisation of the effluent, even of the dry-weather flow, be relied upon at all times and all seasons, having regard to the break-downs in plant and machinery, and to the occasional want of proper care and attention in the control of the working that must be regarded as inevitable in practice.

If money must be spent in safeguarding the water-supplies of the community, it would appear, in a far stronger

degree, preferable to take such steps as are considered necessary to purify a suspicious water after its collection, and prior to its distribution to the consumers. By this method a very much greater degree of certainty can be imparted to the problem of the protection of the community from disease than by the more or less haphazard endeavours to sterilise the sewage effluents which a stream receives in its course. Finally, there is a general agreement that, even if an attempt were made to sterilise such effluents, the interests of the water consumers would still render necessary an efficient purification plant at the waterworks.

This is the view, indeed, taken by the Royal Commissioners on Sewage Discharge, who, in their fifth Report, say: "In our opinion the cost of reconstructing the sewers, so as to allow of the abolition of storm overflows, together with the cost of providing and maintaining purification plant, which could be relied on at all times to render the total refuse waters of a town both chemically and bacteriologically pure, would in most cases be practically prohibitive; and, further, even if this additional burden were placed on local authorities, the water of rivers would generally still require to be treated before it could be safely distributed for drinking purposes. . . . Generally speaking, therefore, we do not consider that in the present state of knowledge, we should be justified in recommending that it should be the duty of a local authority to treat its sewage so that it should be bacteriologically pure."

Dr. Houston, in his work at the laboratories of the Metropolitan Water Board, has shown that, if sufficient storage capacity is provided in the reservoirs for the crude river water from the intakes, it is possible to eliminate from the water all but a very minute percentage of

disease-producing organisms. In eighteen experiments with unfiltered water, infected with enormous numbers of the bacilli of enteric fever, it was found that over 99 per cent. of these organisms died as the result of simple storage of the water for four weeks.

By storage, then, for a sufficient length of time, followed by sand filtration on modern lines, it would appear to be possible to render reasonably safe a river water which receives in its course crude sewage and sewage effluents; and the cost of the work requisite to ensure this result could be undertaken with the assurance that the safety secured would be of infinitely higher value than that which could be attained by relying on the problematical sterilisation of the sewage and sewage effluents discharged into the river used as a source of supply.

The Treatment of Storm Waters

We have already considered the undesirability of allowing the storm and surface waters, collected in a separate system of sewers to that which receives the soil drainage of houses, to be discharged into a stream without any sort of purification.

The necessity for purifying the storm waters conveyed by a combined system of sewerage is even more urgent, as the first flush of storm water through the sewers washes out a large quantity of foul sediment, and renders the liquid which first escapes through storm-water overflows organically more impure than the ordinary dry-weather sewage. If this liquid is passed without treatment into a stream, very serious nuisance is apt to result.

The fifth Report of the Royal Commission on Sewage Discharge deals with this subject of the treatment of storm

waters (p. 209). In the first place, the Commissioners say that, whilst it is probably impracticable to dispense altogether with storm outflows on *branch* sewers, they think these should be used sparingly, and, where used, should be set so as only to come into operation with a certain defined increase of flow, such increase to be determined by the Rivers Board, or the County Council of the district, the local sewerage authority to have a right of appeal to a central authority to be constituted.

As regards the treatment of storm-water sewage at sewage works, the usual requirements of the Local Government Board are that any increase in flow up to three times the normal dry-weather rate should be fully dealt with by the ordinary complete plant, and that a certain number of additional dilutions—up to a total of six—should be treated on special storm filters.

The Commissioners think these requirements should be modified, as being too inelastic, experience having shown that special storm filters, which are kept as stand-by filters, are not efficient, as their oxidising efficiency in dry weather becomes impaired. The injury done to rivers by the discharge into them of large volumes of storm sewage chiefly arises from the excessive amount of suspended solids which such sewage contains. These solids can be very rapidly removed by settlement.

The Commissioners, therefore, recommend that special stand-by tanks should be provided at the works, and kept empty for the purpose of receiving the excess of storm water which cannot properly be passed through the ordinary tanks. The rate of flow in storm times through the ordinary tanks may, they think, continue to be as before—up to three times the normal dry-weather flow; but above this quantity the sewage should be made to flow into the "stand-by"

tanks. The only overflow at the works into a stream should be from these special tanks, after the tanks are filled. No special storm filters should be provided, but the ordinary filters should be large enough to deal with all the sewage that requires to be so treated.

As regards the overflow from the outfall sewer to the stand-by tanks, the size of the latter, and the amount of storm sewage which should be filtered, the Rivers Board or the County Council should have similar powers to those proposed in regard to overflows on branch sewers, the local authority also having a similar right of appeal to the central authority.

Discharge of Sewage and Sewage Effluents into Estuarial Waters

The discharge of crude sewage into estuarial waters is occasionally permissible, but there are many cases in which, in the interests of the public health, town sewage should be purified before being so discharged.

The Royal Commission on Sewage Discharge, in their fourth Report, comment on the evidence of Dr. Thresh, Medical Officer of Health to the County of Essex, who stated that the districts in Essex bordering on the Thames, in which crude sewage is discharged on to the foreshores, have had a very much higher mortality from enteric fever than the other parts of the county, this being not an accidental occurrence, but one taking place regularly every year. Evidence was also given that offensive emanations from sewage-polluted tidal rivers may cause general deterioration of the health of the people living near the river, and more particularly give rise to the prevalence of sore throats.

The problem of sewage purification in its relation to

oyster, mussel, and cockle beds on the foreshores of tidal waters is a very difficult one. The same Royal Commission (fourth Report) states that it is clear from the exhaustive survey of the oyster fisheries of England and Wales, which was made by Dr. Bulstrode in 1894–5, and from a similar survey in Ireland, that many layings and ponds around our coasts are so situated that sewage may reach them in a very short time after its discharge from the outfall; and it is well known that micro-organisms of intestinal origin may be taken up by shell-fish from the water in which they are lying, and such microbes may remain alive in them for several days. There have been numerous instances in which several persons have been simultaneously seized with enteric fever, and the only discovered competent cause, common to all the cases, was the eating of shell-fish. In some of these instances the source of the shell-fish has been traced, and the layings found to be so situated as to be obviously liable to sewage contamination.

The Commissioners point out that it is not at present possible to define with certainty the limits to which dangers due to the discharge of sewage into a tidal river or estuary may extend. Analyses of examples of some of the purest waters, in which native oysters are fattened, have shown that *B. coli*, or coli-like microbes, may not uncommonly be detected in 10 c.c., and sometimes in 1 c.c., of such waters. It is, therefore, impossible to condemn oysters merely because *B. coli* is present in their bodies, or in the water within their shells; but, as a general rule, Dr. Houston finds that a very much smaller number of *B. coli*, or coli-like microbes, is found in oysters stored in pure waters than in oysters stored in polluted waters.

From what has been said, it will be apparent that no great reliance can be placed upon the sterilisation of sewage

or sewage effluents before discharge into tidal waters. Oysters taken from layings open to pollution by sewage might be relayed in pure waters, with the view of giving them time and opportunity to rid themselves of any micro-organisms which could give rise to disease. The Royal Commissioners were unable (in their fourth Report) to make any precise statement as to the effect of such relaying, and they think that further systematic investigation of the question is required.

It is probable, however, that it is in this direction that will ultimately be found the possibility of delivering oysters from the suspicions that now attach to them. It will be necessary, however, in order effectually to safeguard the public health, that some legal authority should be given to a Statutory Board or a Commission, to require that all oysters taken from layings liable to pollution should be relaid in pure water for a certain definite period of time, before being placed on the market. As to what steps, if any, can be taken to render innocuous mussels and cockles that have been derived from polluted waters, there is at present no evidence. The only measure of safety at present is their condemnation and destruction as unfit for the food of man.

Pollution of Water-cress

The dangers attaching to the use as food of oysters, cockles, and mussels from polluted reaches are now well known to be also incidental to water-cress taken from sewage-contaminated waters. The only preparation for table that water-cress receives is a more or less perfunctory washing under a stream of water from a tap or in a basin. It is easy to understand how the cleansing of the

water-cress in this manner fails to remove from leaves or stalks the slimy matters deposited by sewage, in which may be present pathogenic organisms.

Having regard to the little prospect there is of ensuring that sewage effluents shall be rendered innocuous by sterilisation, and to the great uncertainty attaching to the distance which crude sewage or sewage effluent must travel in a running stream before it loses its capacity for mischief, it would appear to be desirable that water-cress should only be cultivated in waters practically free from any chance of sewage pollution, and that those beds which are supplied with the polluted waters of streams that cannot be freed from sewage impurities, should be closed under powers to be accorded to County Councils or other local sanitary authorities.

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